400 lb

8-ft Alaskan Halibut

STATUS OF CERES CLOUD PRODUCTS

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CERES Science Team Meeting, Williamsburg, VA

November 2, 2004

CERES Cloud Products

Provide consistent dataset from *TRMM, Terra, & Aqua* to

- **Relate cloud properties to the radiation budget**

- **Develop new bidirectional reflectance models for interpreting broadband radiance measurements**

- **Derive surface and atmospheric radiation budgets & the top-of-atmosphere ERB**

- **Provide data to initialize & validate climate & weather prediction models**

PREVIOUS EPISODES

- **VIRS & Terra MODIS results**
  - monthly mean parameters consistent to within expectations of sampling, spectral differences, r_e(VIRS) smaller due to 3.7-μm cal differences
  - cloud amounts consistent with surface climatology, except at poles, cloud amount < ISCCP
  - SW fluxes computed with cloud results ~6 Wm^{-2} < CERES
  - LW fluxes computed with cloud results ~1 Wm^{-2} < CERES
  - mean stratus droplet sizes within 1 μm of surface values over ARM SGP
  - mean stratus OD within 4% of surface values over ARM SGP
  - mean stratus LWP within -18 to +16% of surface values over ARM SGP
  - most cloud heights within 1 km, daytime thin cirrus tends to bias low
  - cirrus optical depths in good agreement over ARM SGP

CALIBRATION

- **Extensive ongoing intercalibration effort**
  - intercalibrate VIRS & MODIS; Terra & Aqua MODIS
  - determine stability by comparing imagers to CERES
  - examine all channels of interest (**0.6, 0.86, 1.6, 3.7-3.9, 10.8, 12 μm**)

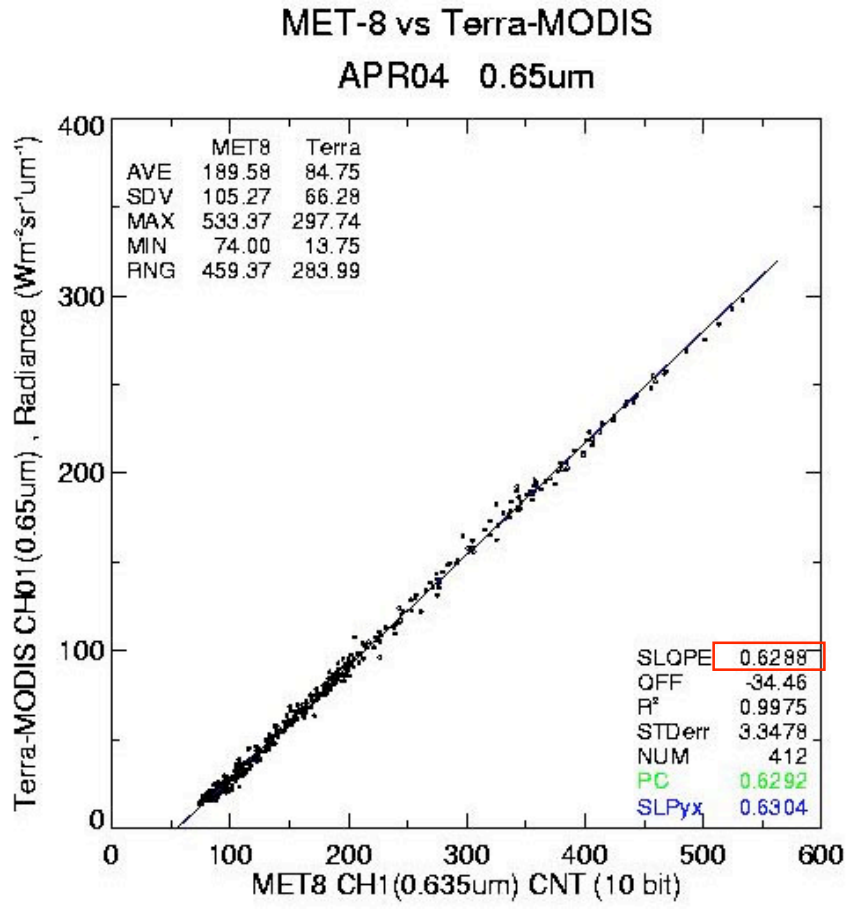
    theoretically account for expected inter-satellite spectral differences
  - use statistics to reduce noise and angular/time matching errors

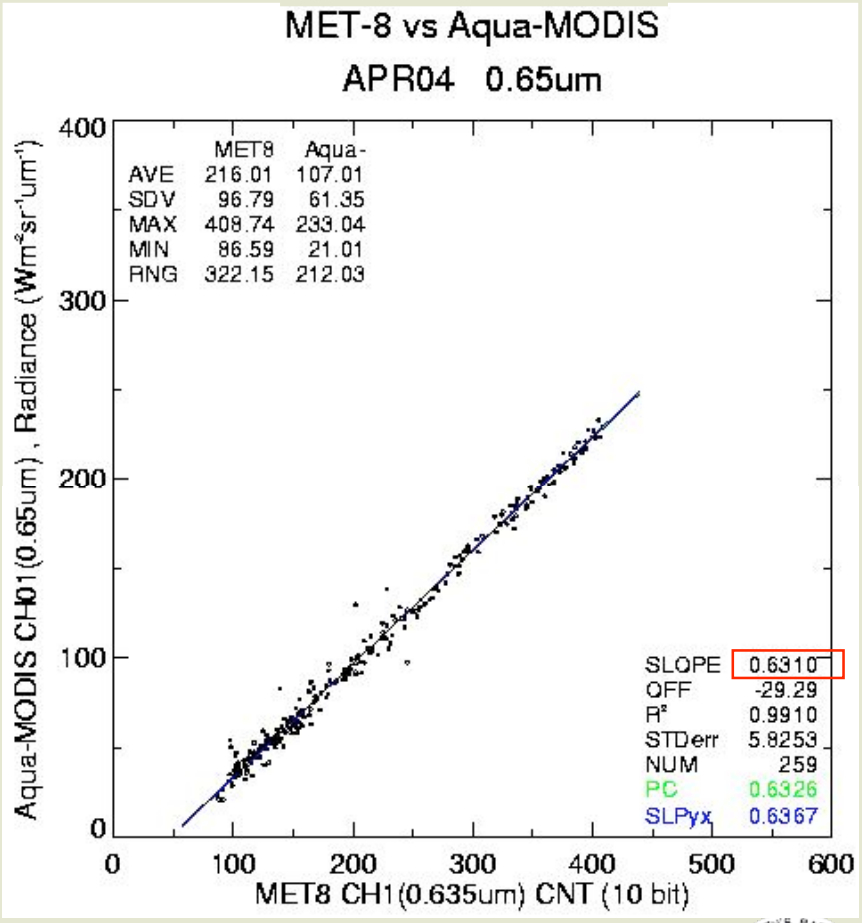
- **Intercalibrate other satellites for CERES & other projects**
  - link all considered satellites to references (VIRS or MODIS)
  - *GOES*-7, 8, 9, 10, 11, 12 (1993 - present)
  - AVHRR: *NOAA*-9,10, 11, 12, 14, 15, 16, 17 (1985 - present)
  - *GMS*-5, *Meteosat*-7 & **SEVIRI on *Meteosat-8***

INTERCALIBRATIONS

Meteosat-8 Calibration Using *Terra*/*Aqua* MODIS

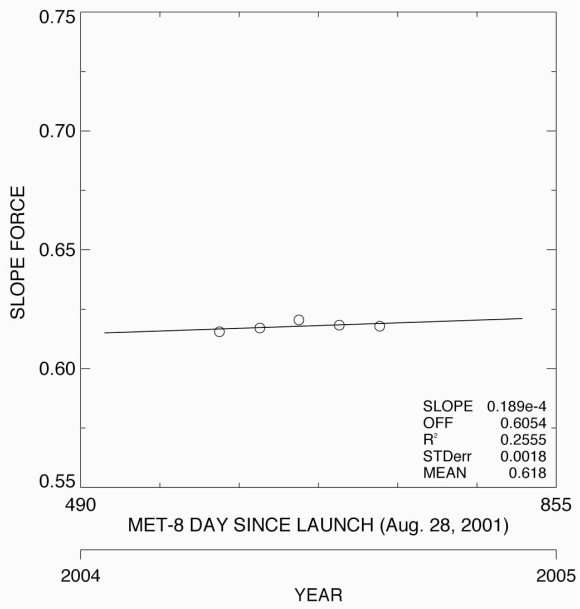
0.635 μm, April 2004





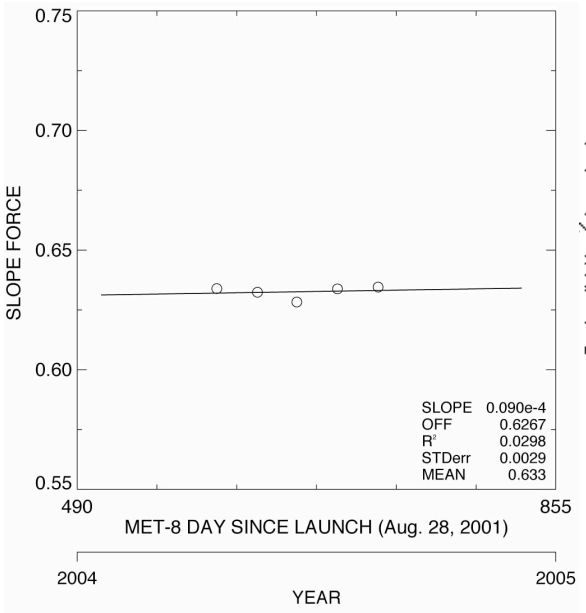
MET-8, visible trend lines

Terra-MODIS
April-August 2004



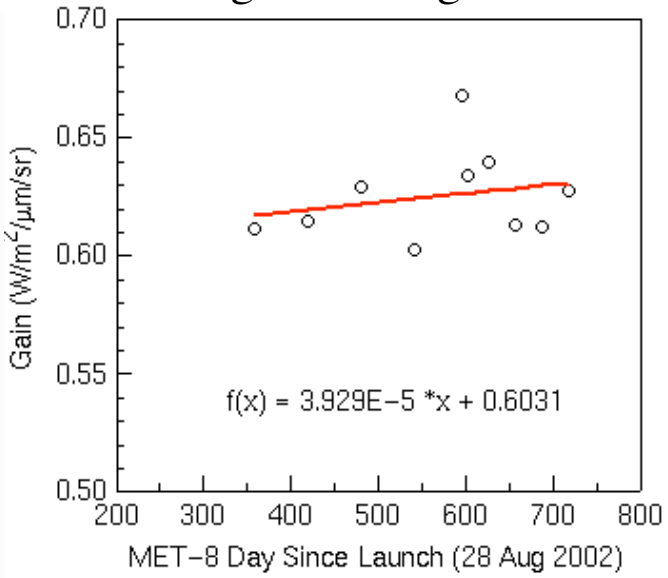
Gain 0.618

Aqua-MODIS
April-August 2004



Gain 0.633

GOES-12/VIRS
Aug 2003-Aug 2004



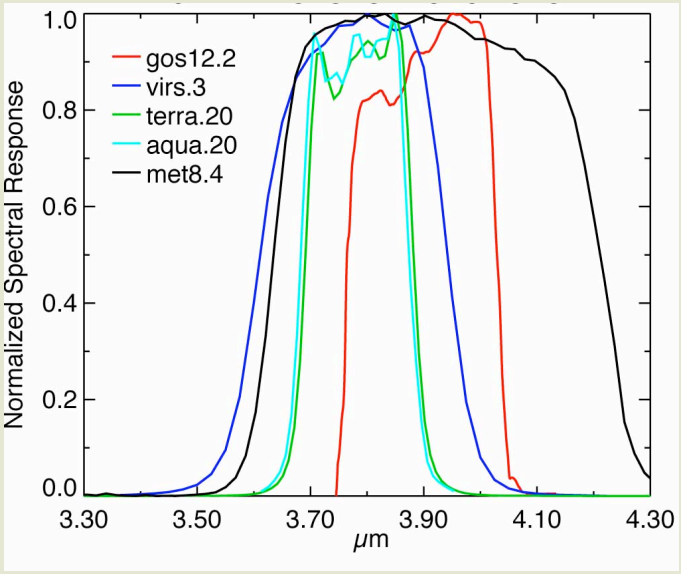
Gain 0.625

M = 1.024 A

MET-8, 3.9 μm, Δ Temperature

April - Aug. 2004, MET8 - reference

Terra	Aqua	GOES-12
-6.7	-6.8	-3.3



Slight changes in the spectral response function can cause large temperature difference between instruments

CALIBRATION STATUS FOR CERES VIRS/MODIS

- *Terra* MODIS VIS up ~ 2% less than Aqua
  - *additional theoretical study needed to warrant changes*
  - *need further comparisons with CERES SW fluxes*
- Terra MODIS vs Aqua MODIS 3.7 μm
  - *earlier results show Terra 0.7 K higher*
  - *current results show Terra & Aqua equal*
- Trend analyses continue & include CERES vs Terra & Aqua MODIS
- IR channels show no significant differences

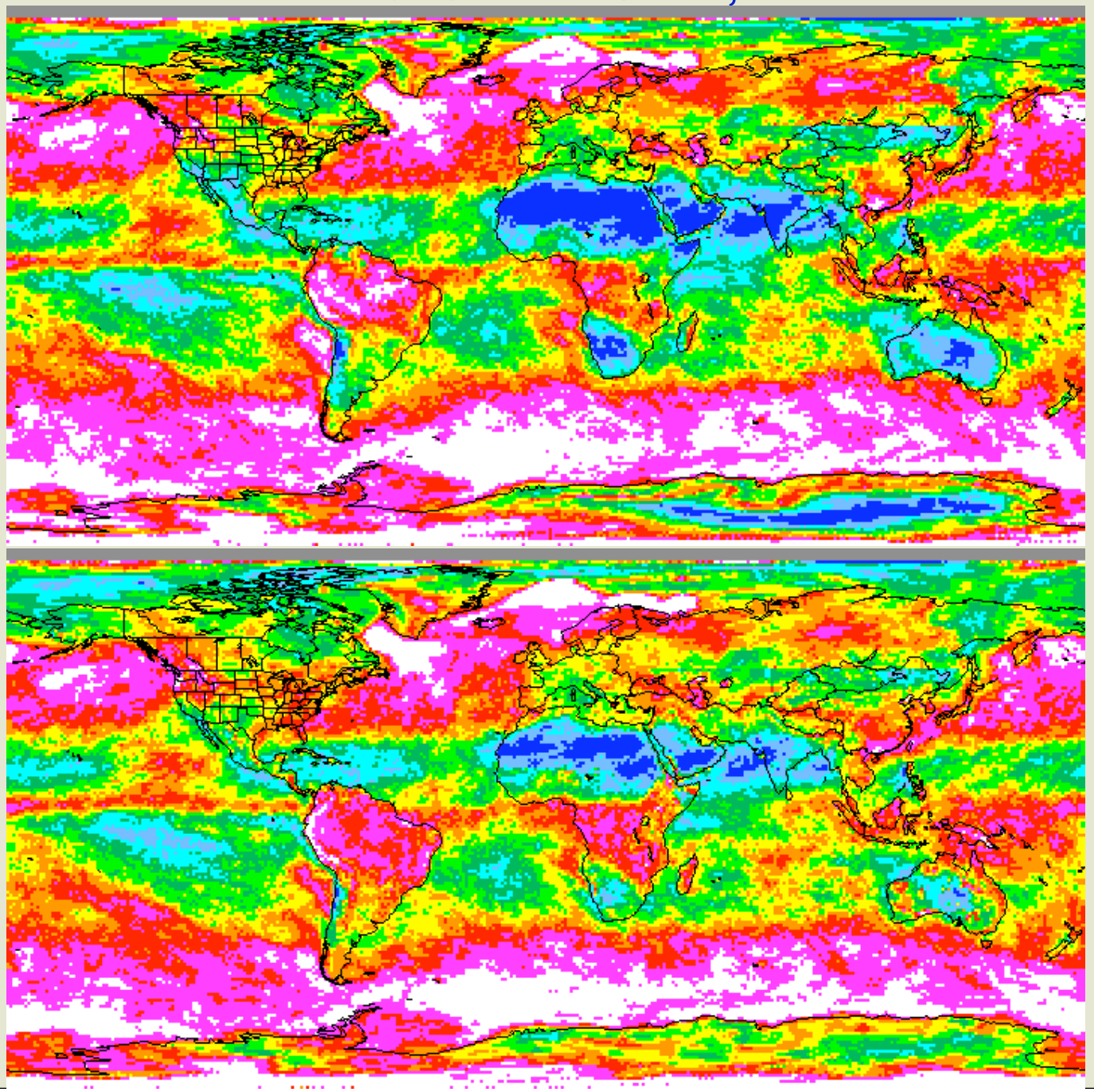
CHANGES IN ALGORITHM FOR Aqua Ed1

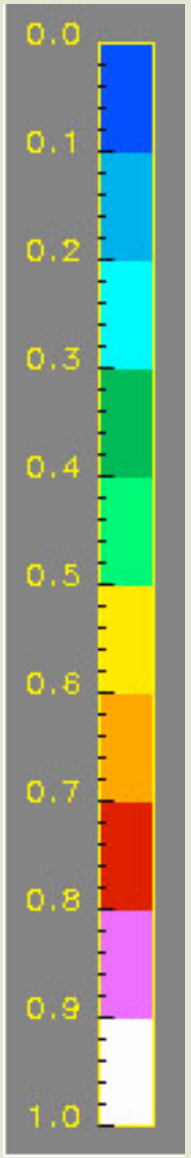
- Cloud Phase Algorithm modified to improve cloud phase over snow
- Water map bugs removed
- Fixed ocean albedo in polar regions to eliminate false snow detection
- No retrievals now retrieved with LBTM (simpler algorithm)
  - increases thin cirrus retrievals
- Daytime non-polar mask
  - new thin cirrus test (8.5-11, ref(1.38), 11-12
  - improved low cloud /snow separation over land
- Daytime polar
  - eliminated many TBD pixels
- Twilight polar
  - improved cloud and snow separation
- Implemented new multilayer algorithm

DAYTIME CLOUD AMOUNT, March 2003

Terra

Aqua





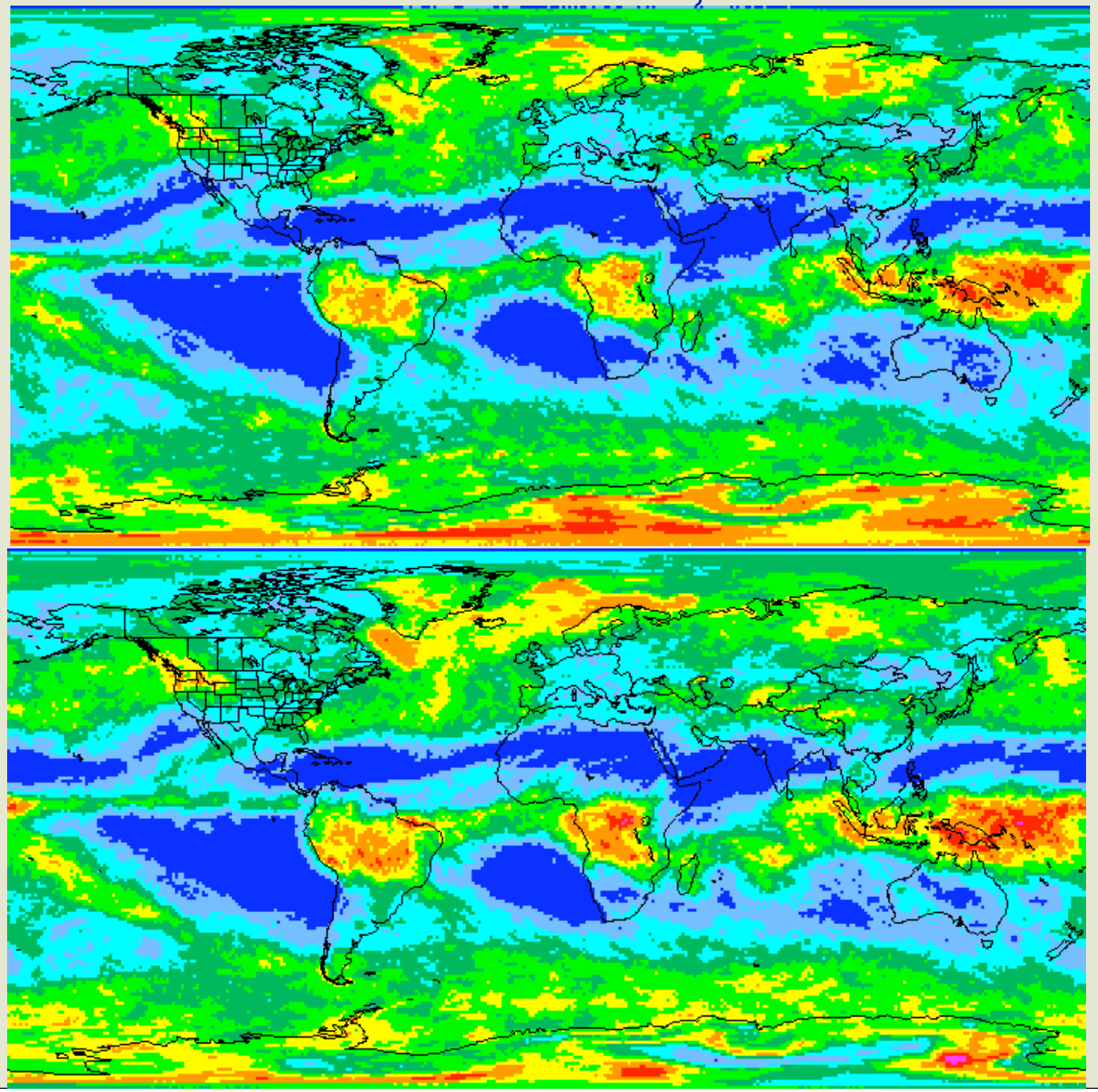
NASA

CERES

DAYTIME ICE CLOUD AMOUNT, March 2003

Terra

Aqua

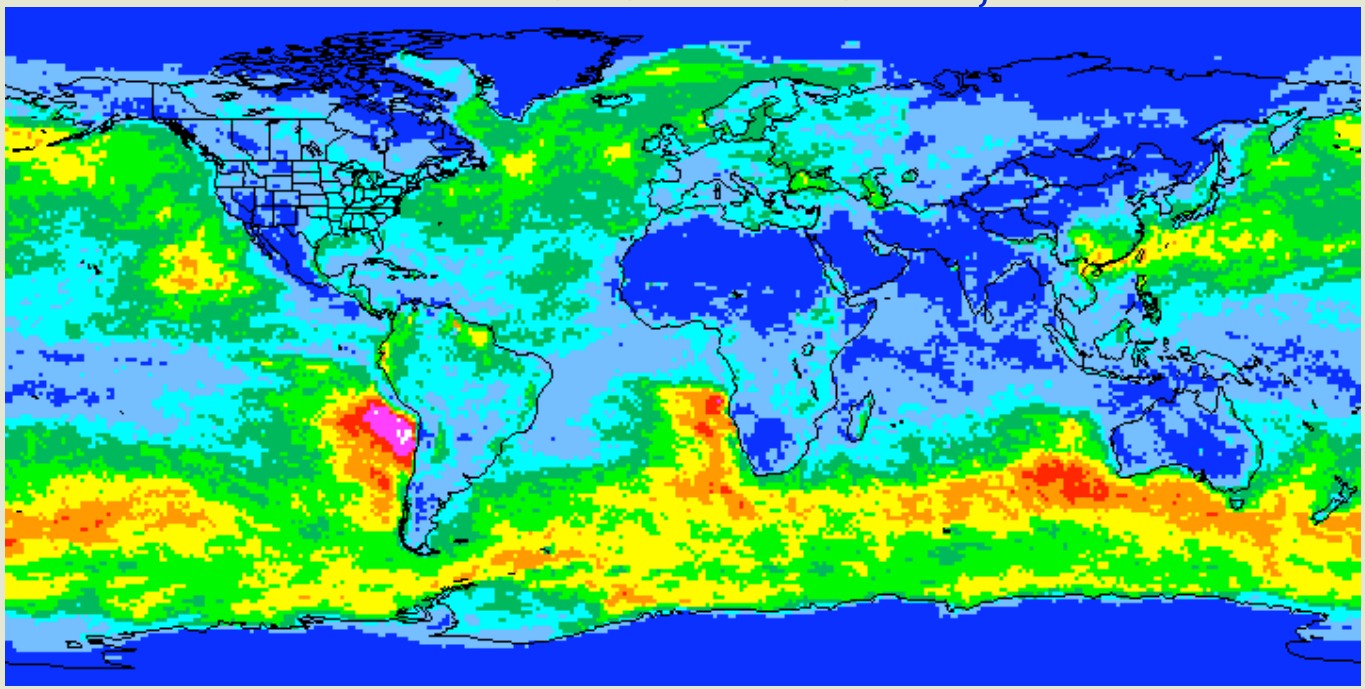


NASA

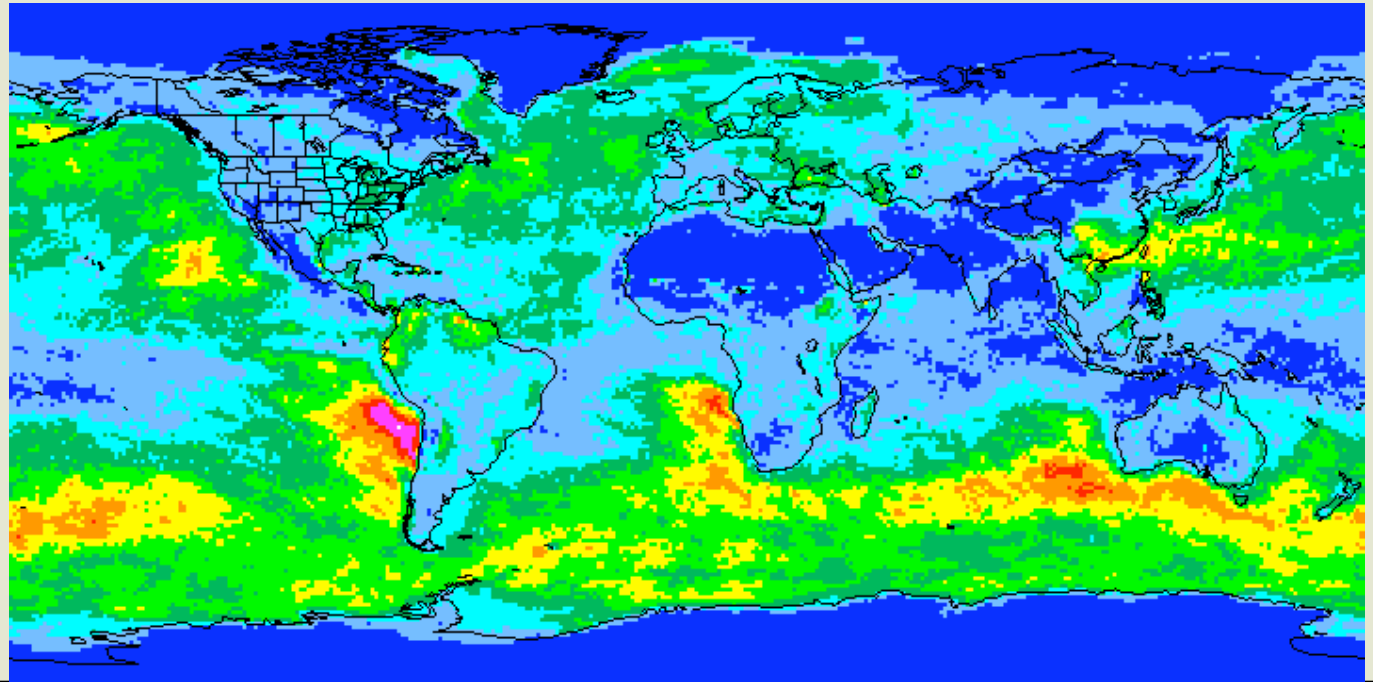
CERES

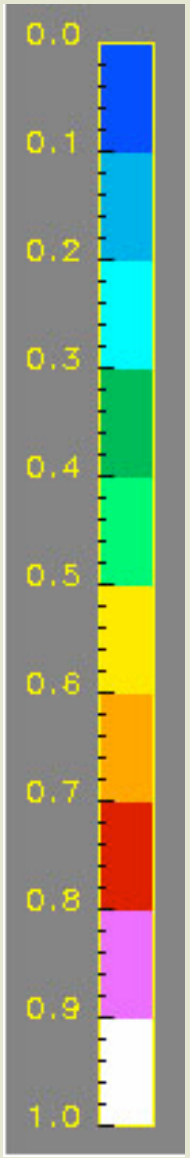
DAYTIME WATER CLOUD AMOUNT, March 2003

Terra



Aqua





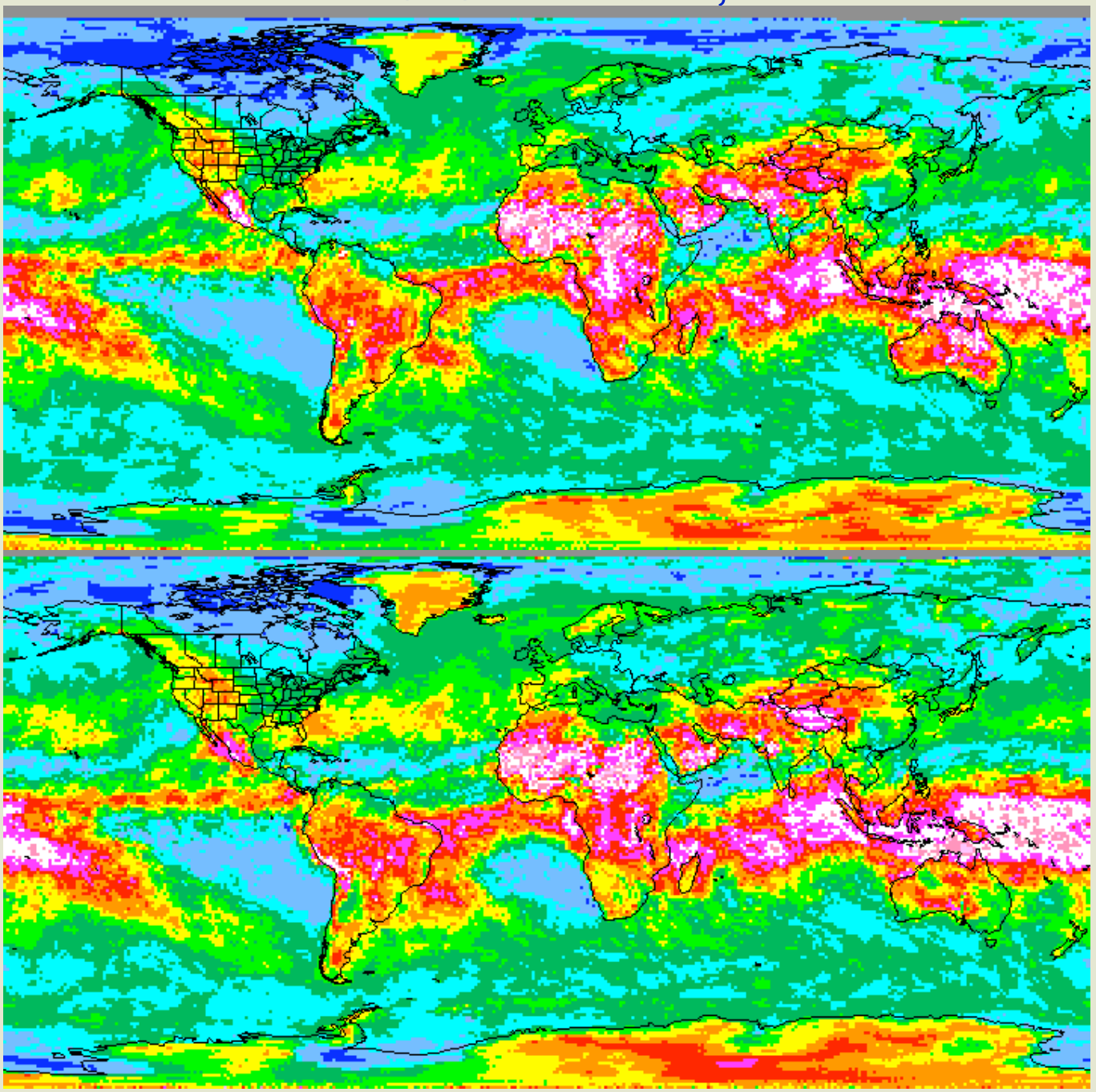
NASA

CERES

DAYTIME CLOUD HEIGHT, March 2003

Terra

Aqua



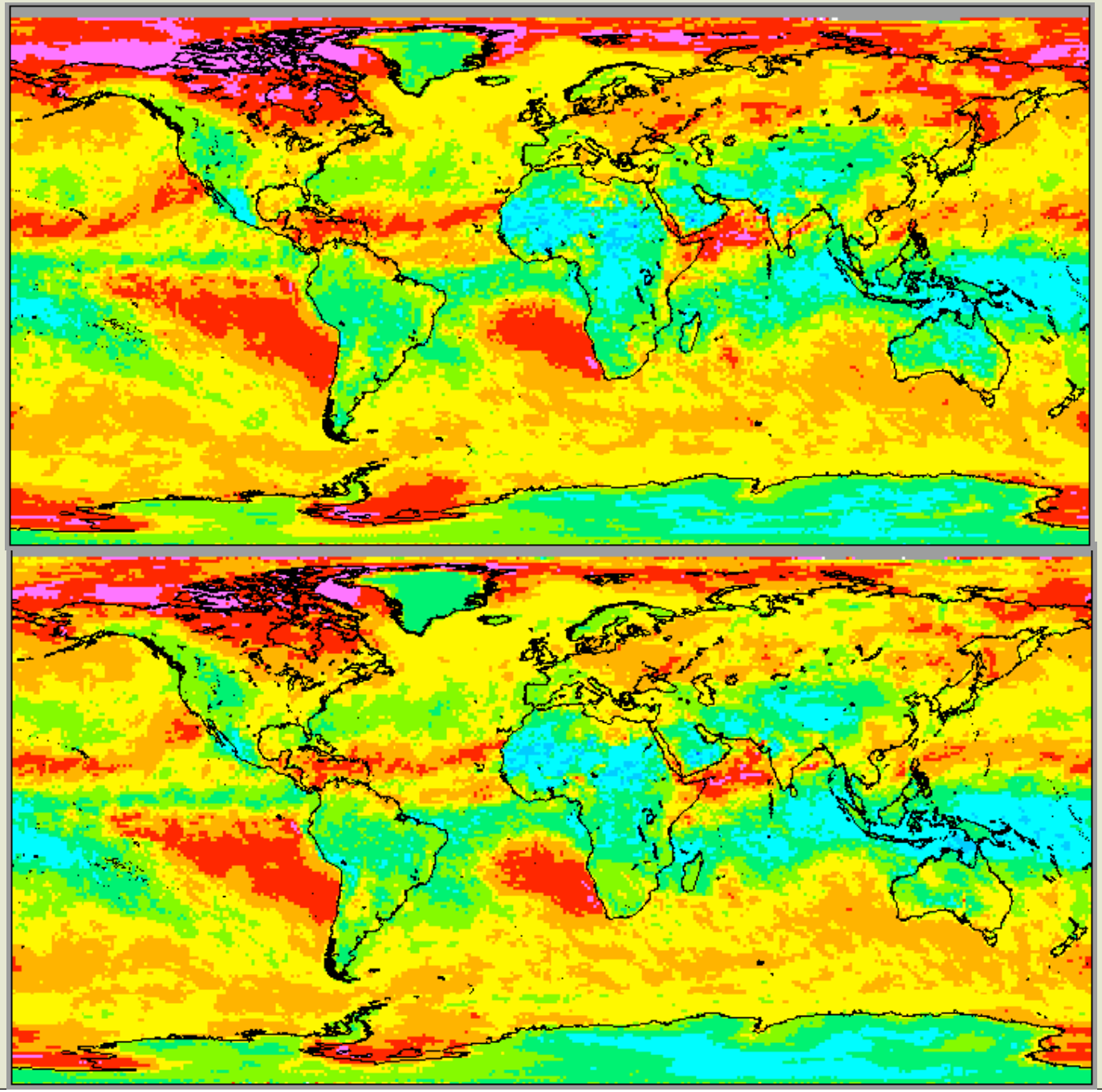
km

1
2
3
4
5
6
7
8
9
10
11
12

DAYTIME CLOUD PRESSURE, March 2003

Terra

Aqua



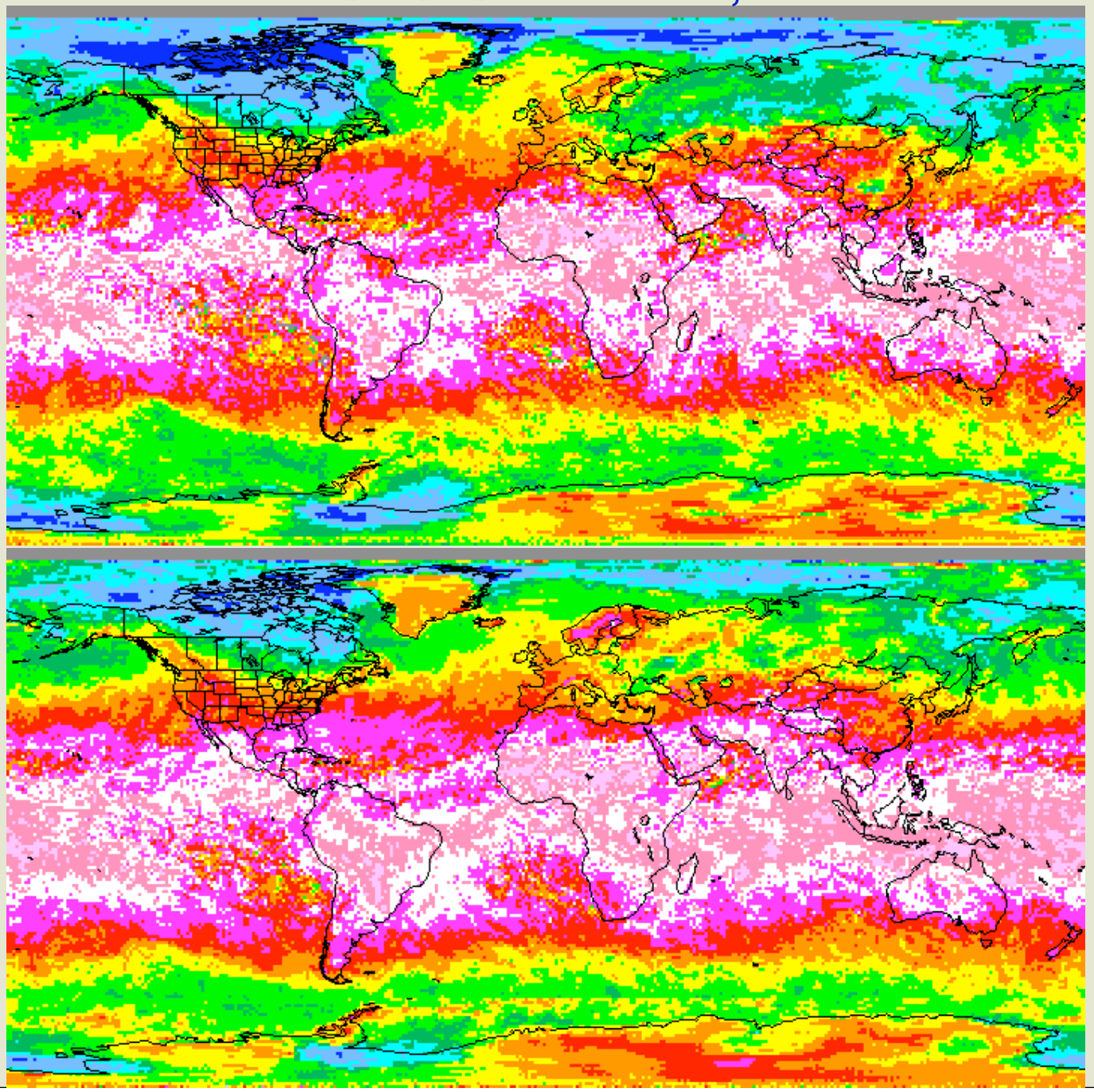
hPa

100
200
300
400
500
600
700
800
900
1000
1100

DAYTIME ICE CLOUD HEIGHT, March 2003

Terra

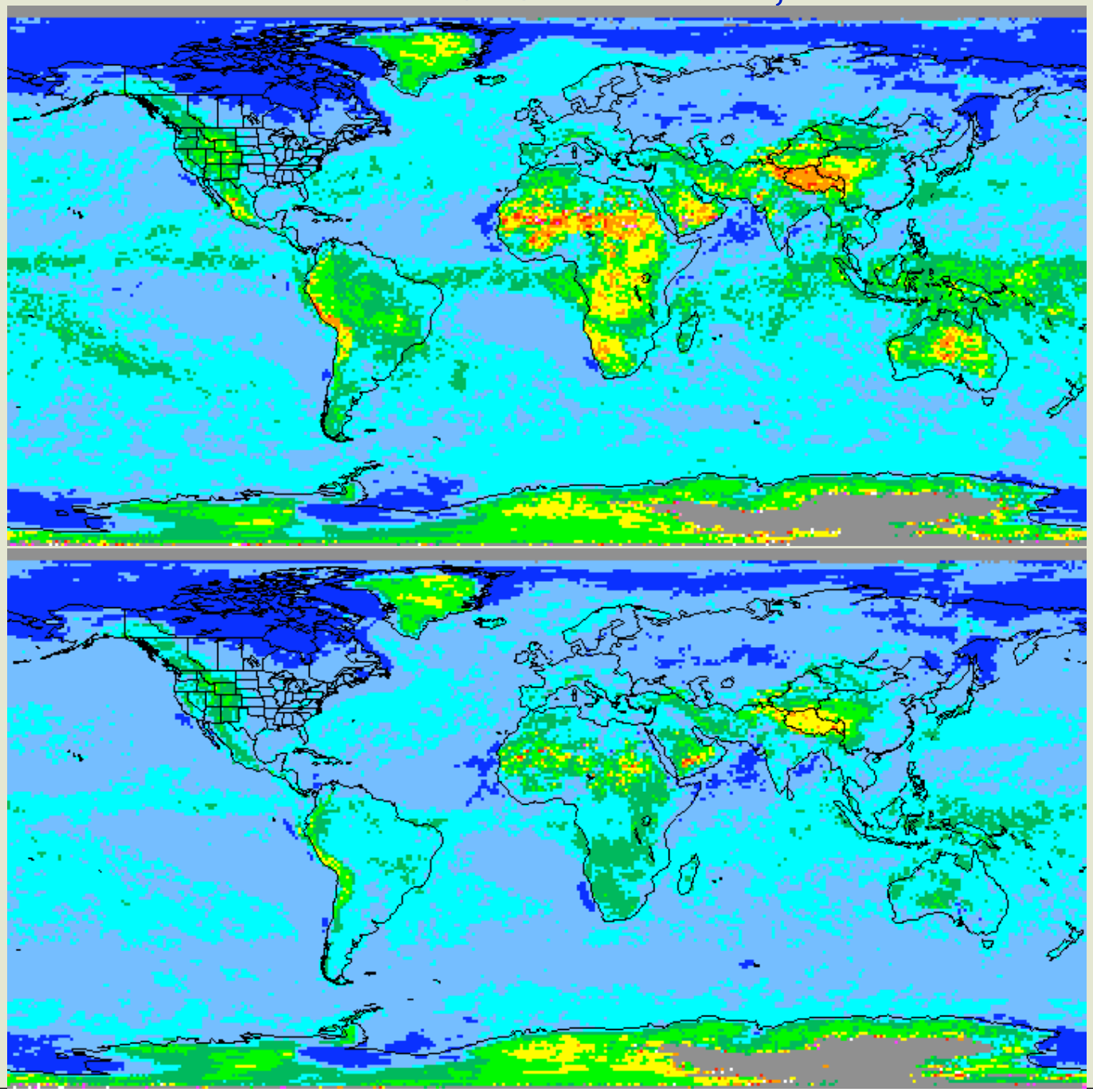
Aqua



DAYTIME WATER CLOUD HEIGHT, March 2003

Terra

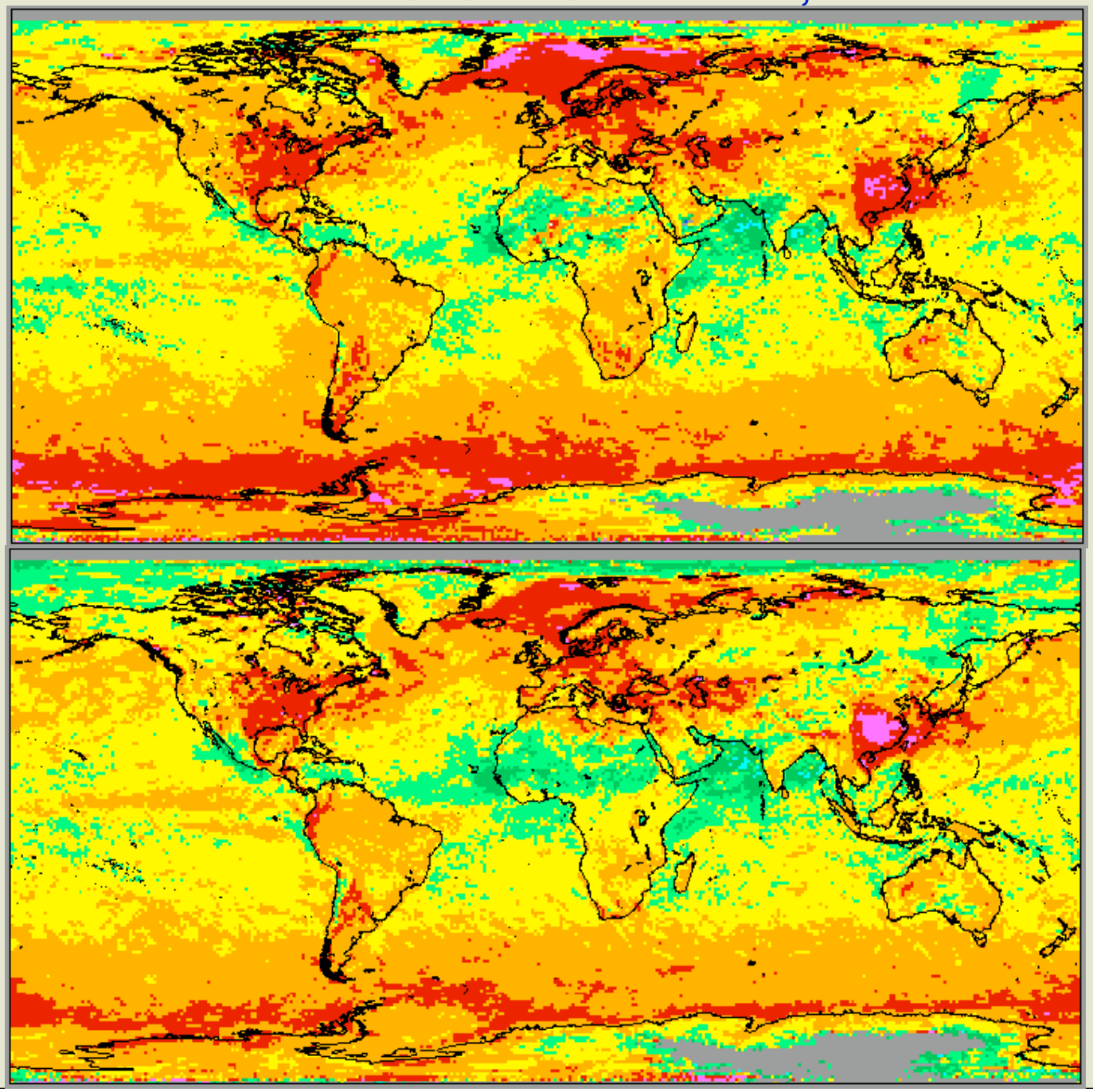
Aqua

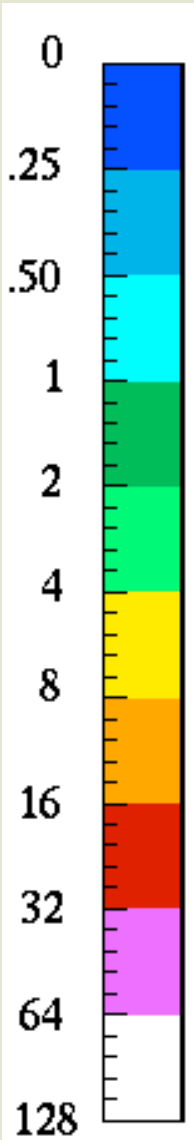


DAYTIME WATER CLOUD OPT DEPTH, March 2003

Terra

Aqua

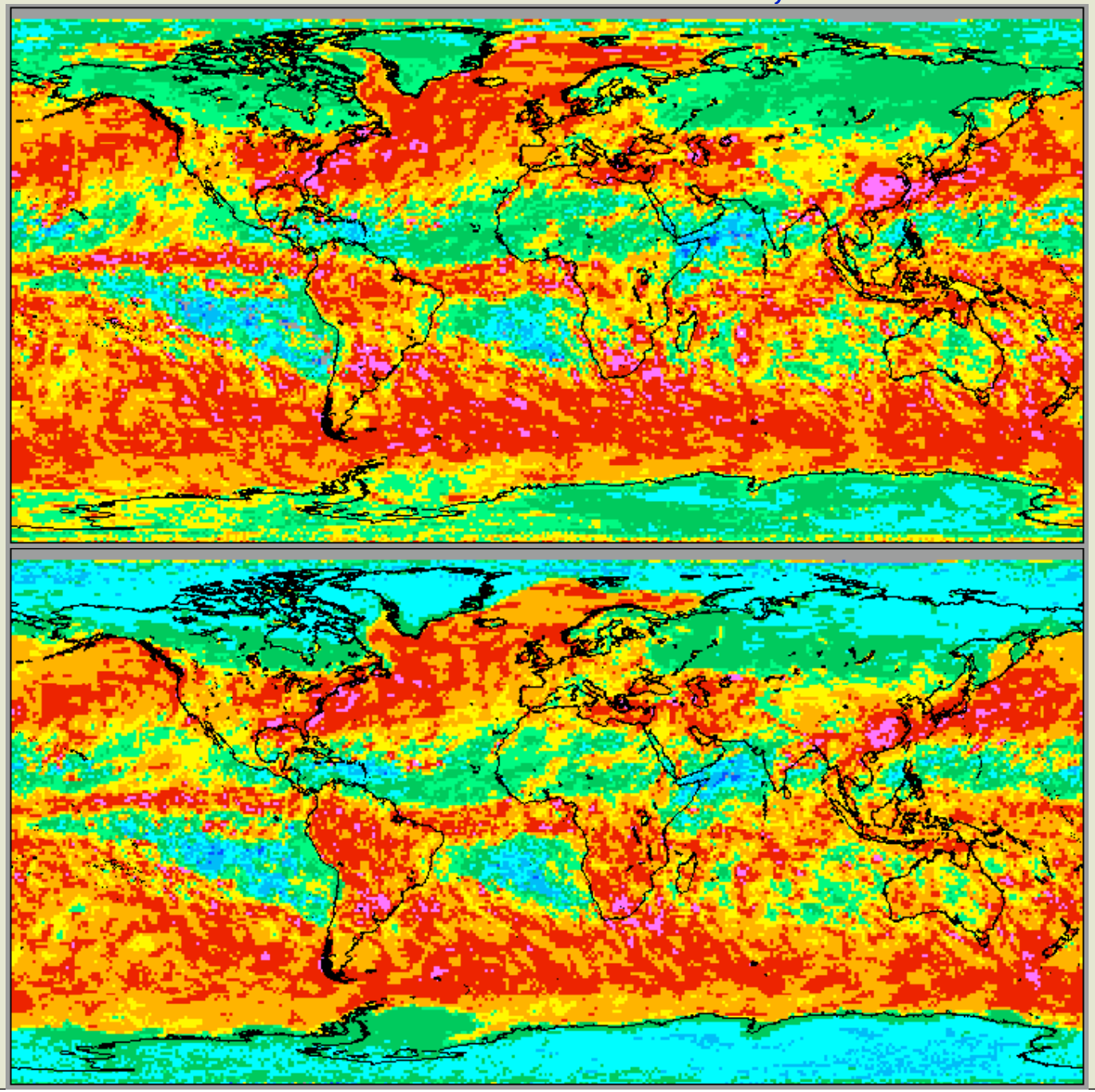


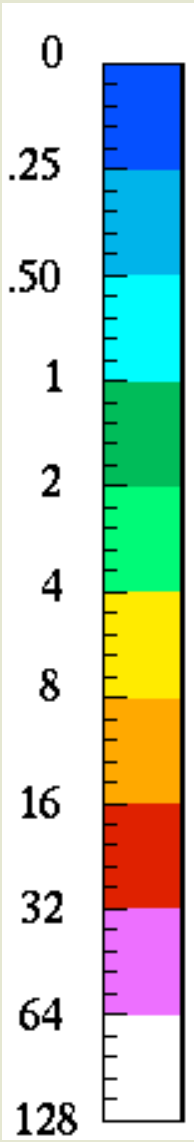


DAYTIME ICE CLOUD OPT DEPTH, March 2003

Terra

Aqua

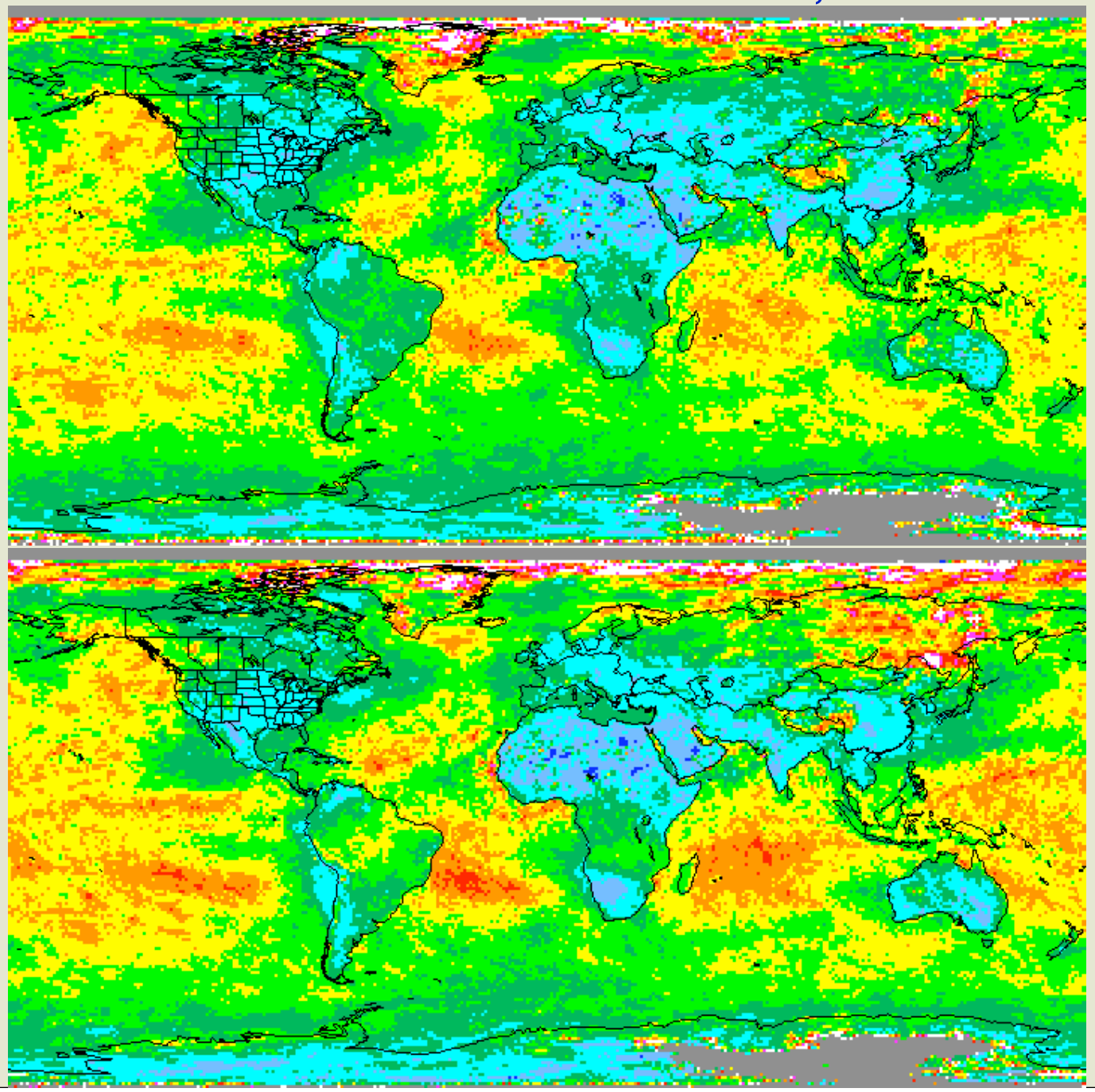




DAYTIME WATER DROPLET RADIUS, March 2003

Terra

Aqua



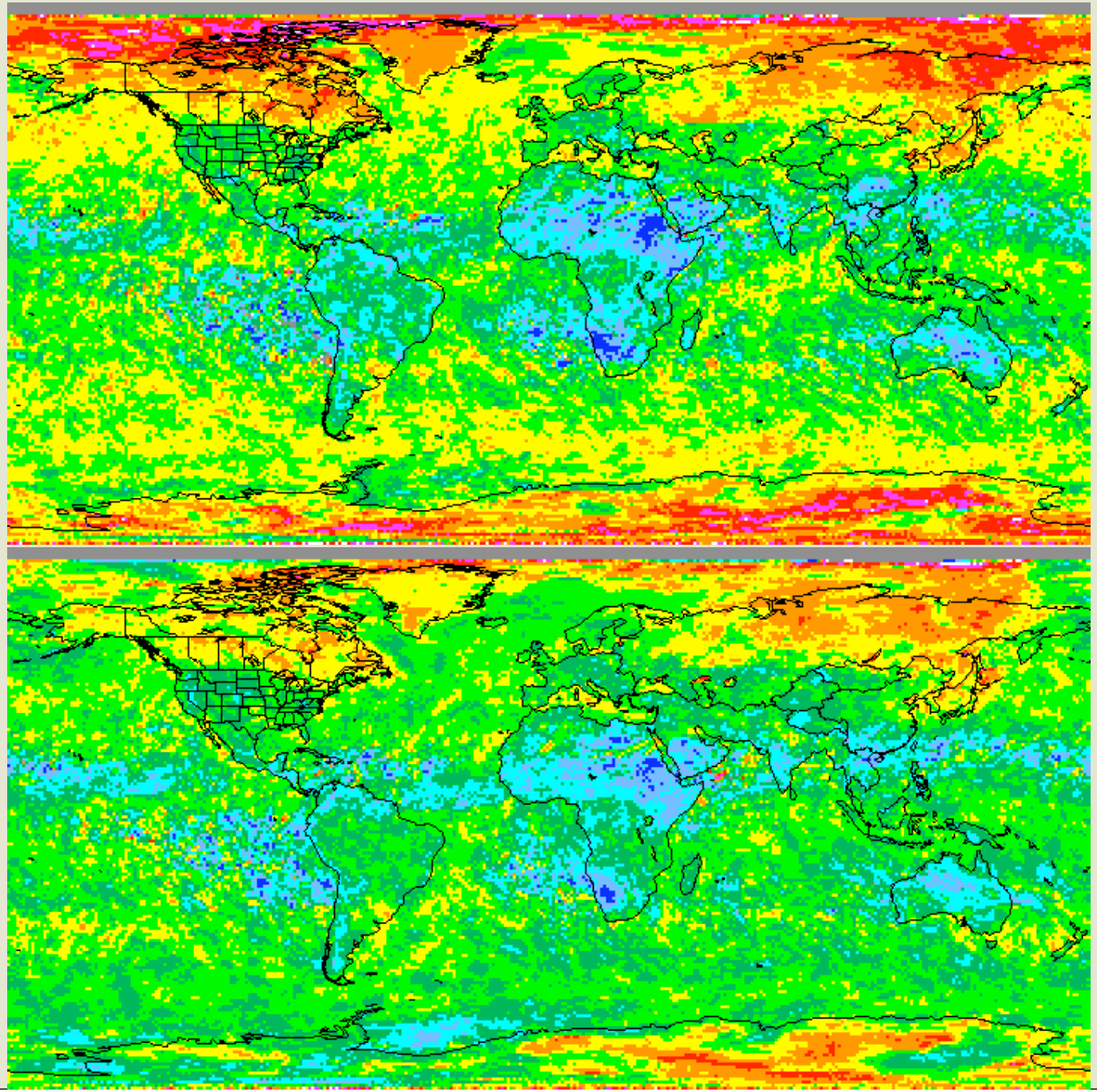
μm

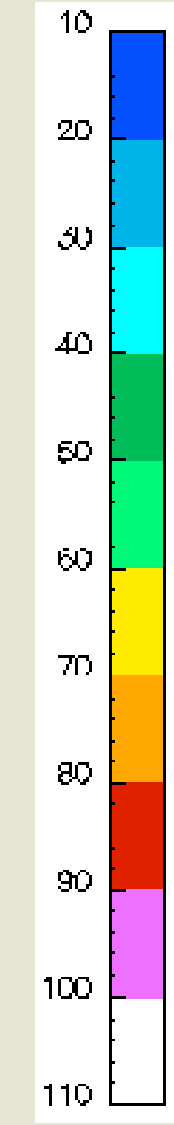
4
6
8
10
12
14
16
18
20
22
24

DAYTIME ICE CRYSTAL DIAMETER March 2003

Terra

Aqua

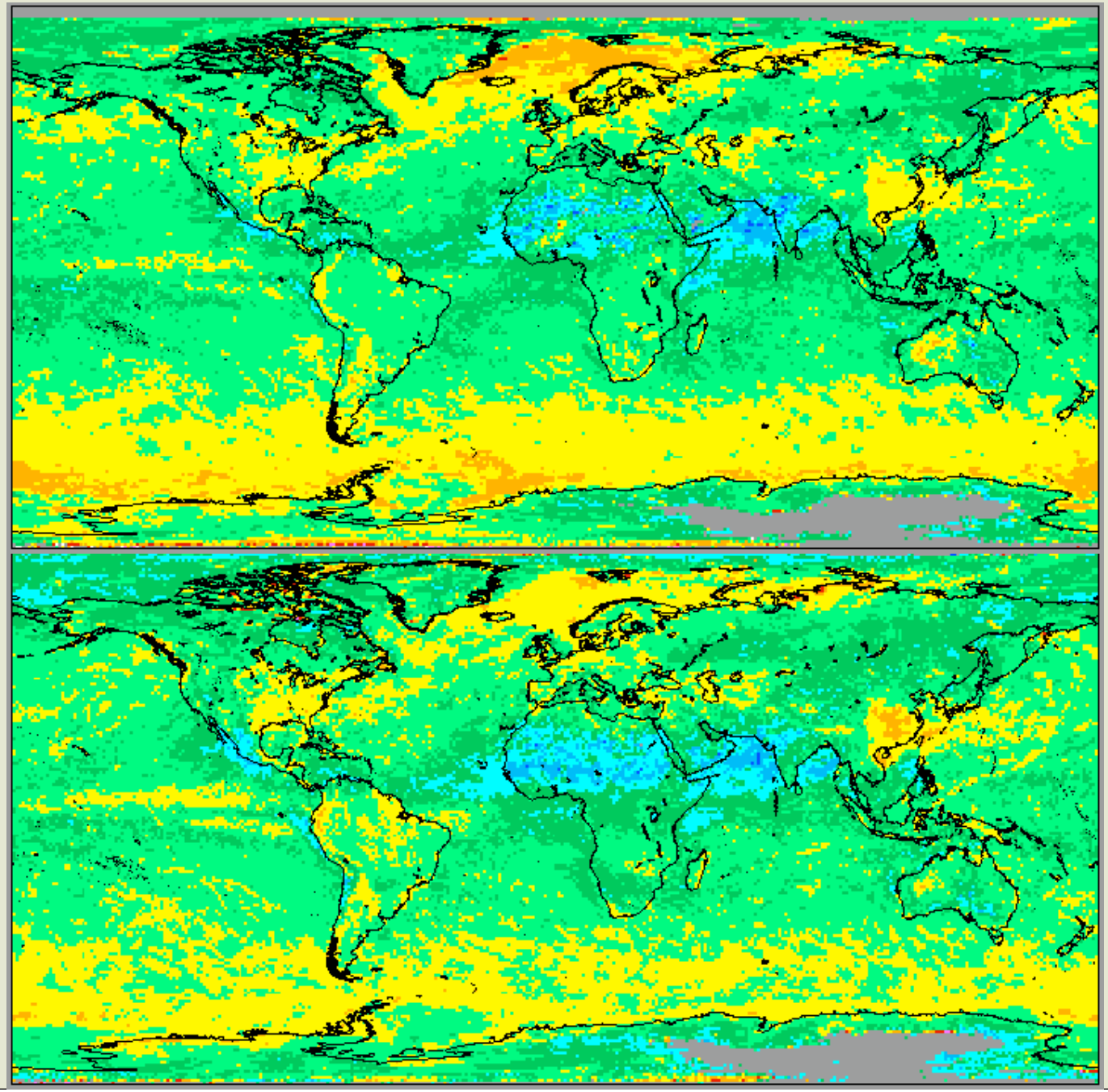




DAYTIME LWP, March 2003

Terra

Aqua



gm^{-2}

0

5.8

11.7

23.4

47.8

93.8

187.5

375

750

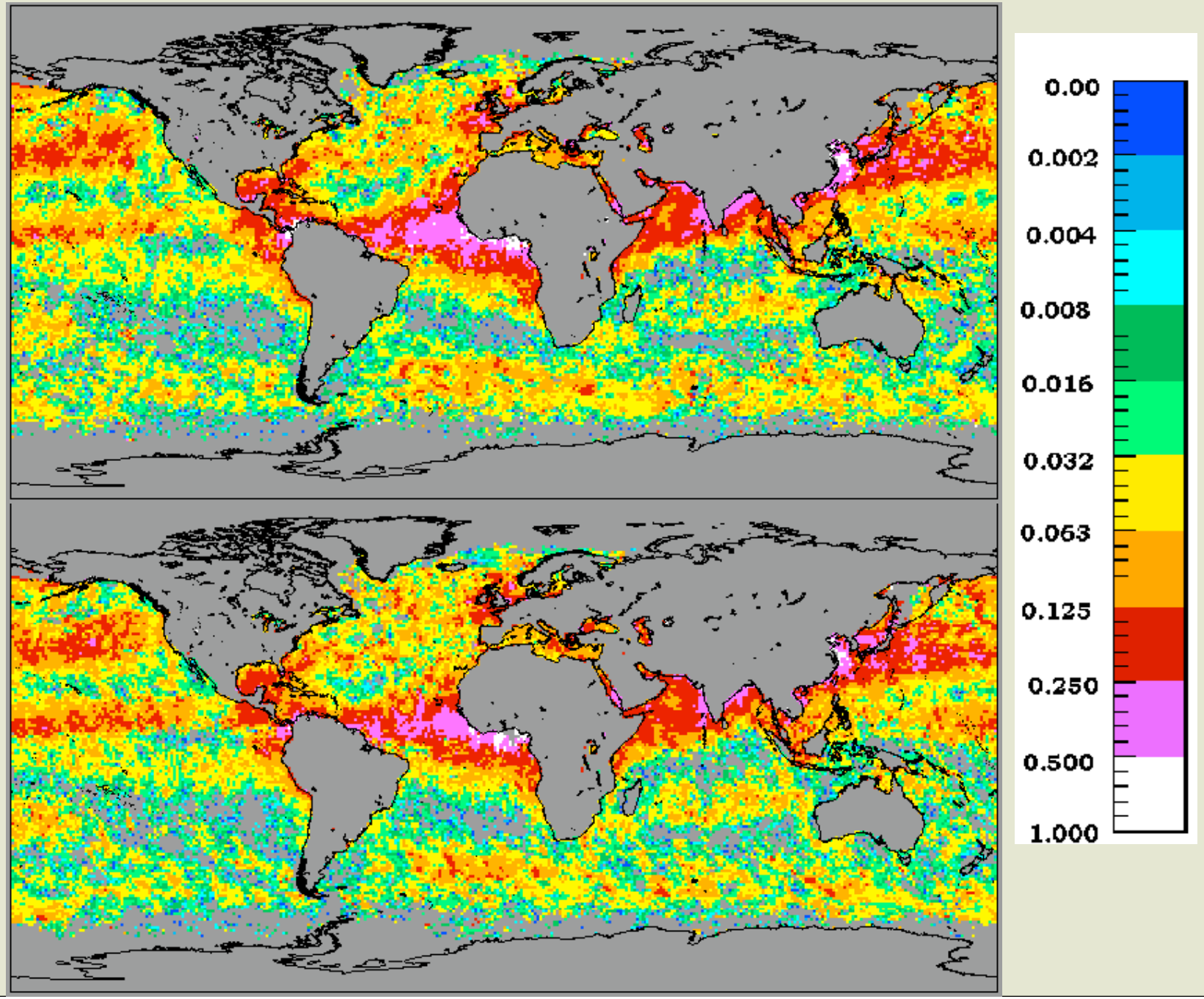
1500

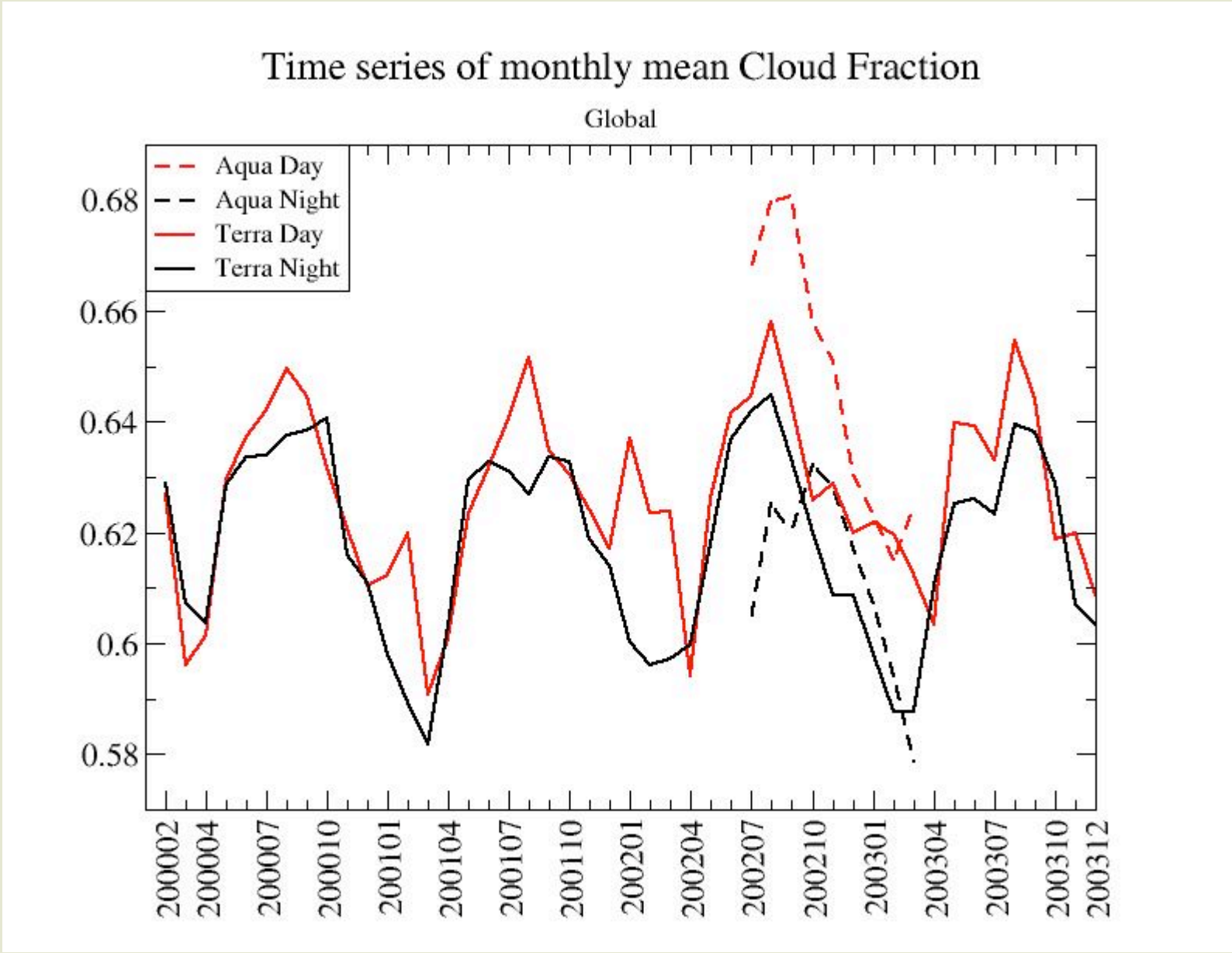
3000

AEROSOL OPTICAL THICKNESS, March 2003

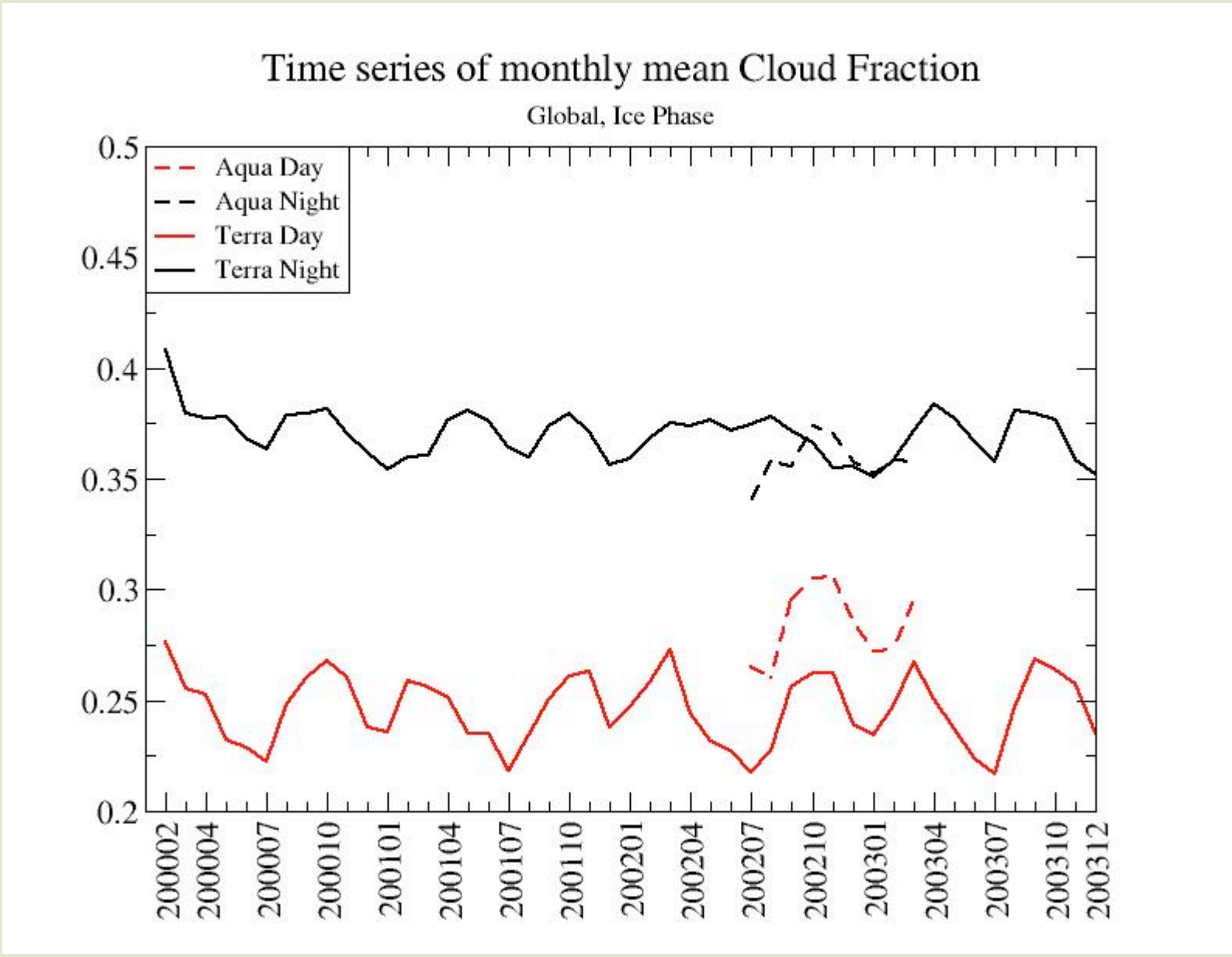
Terra

Aqua

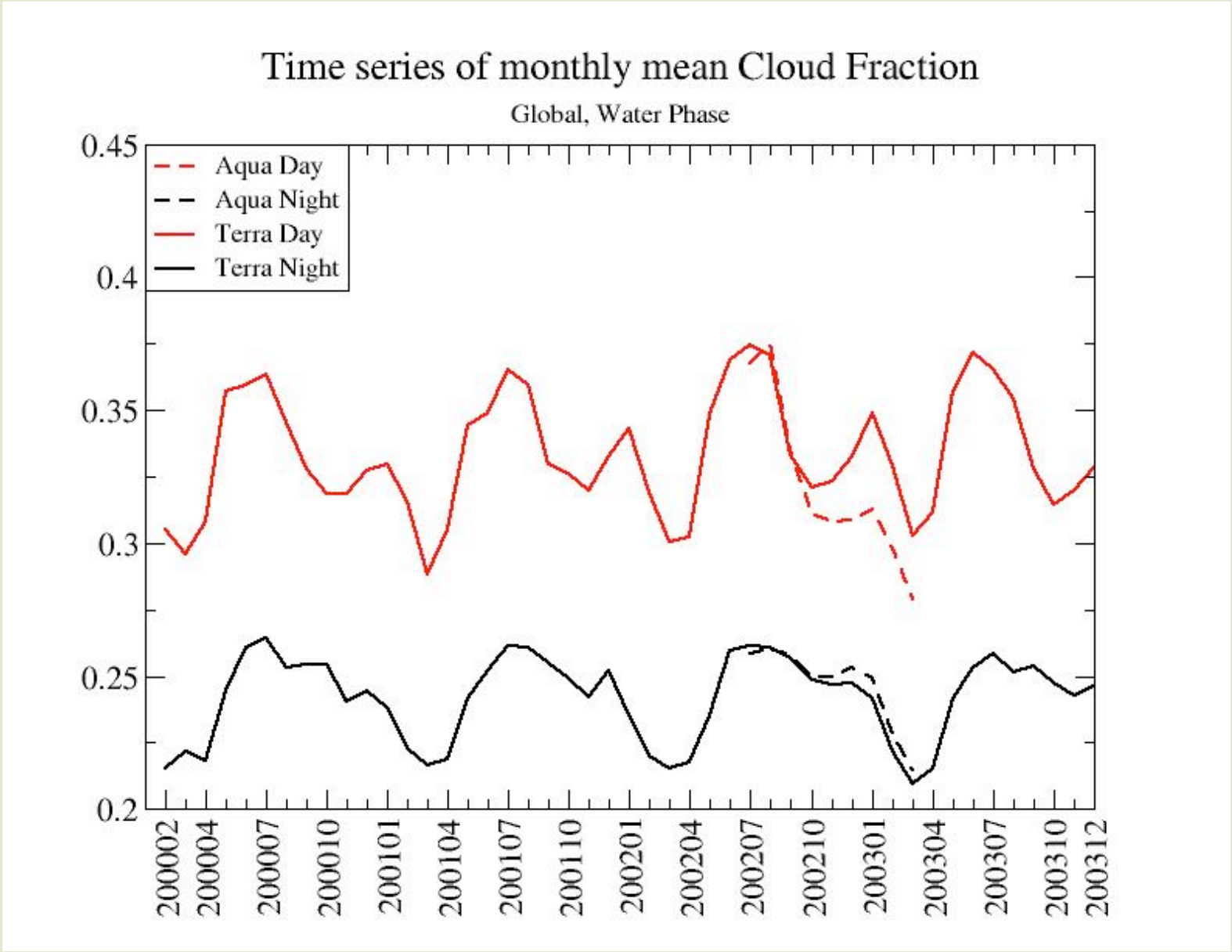




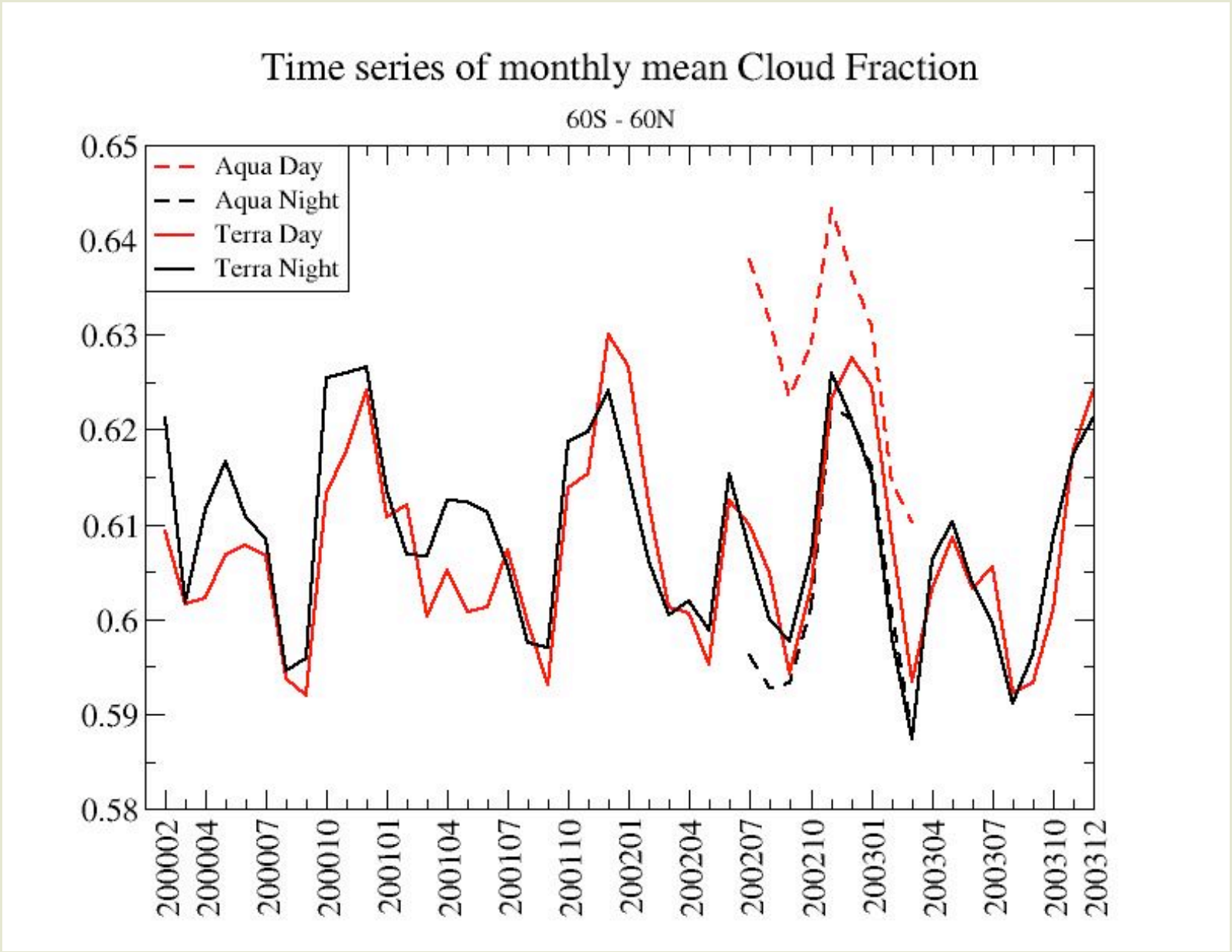
Aqua ~2% greater during day, 3% < to 2% > Terra at night



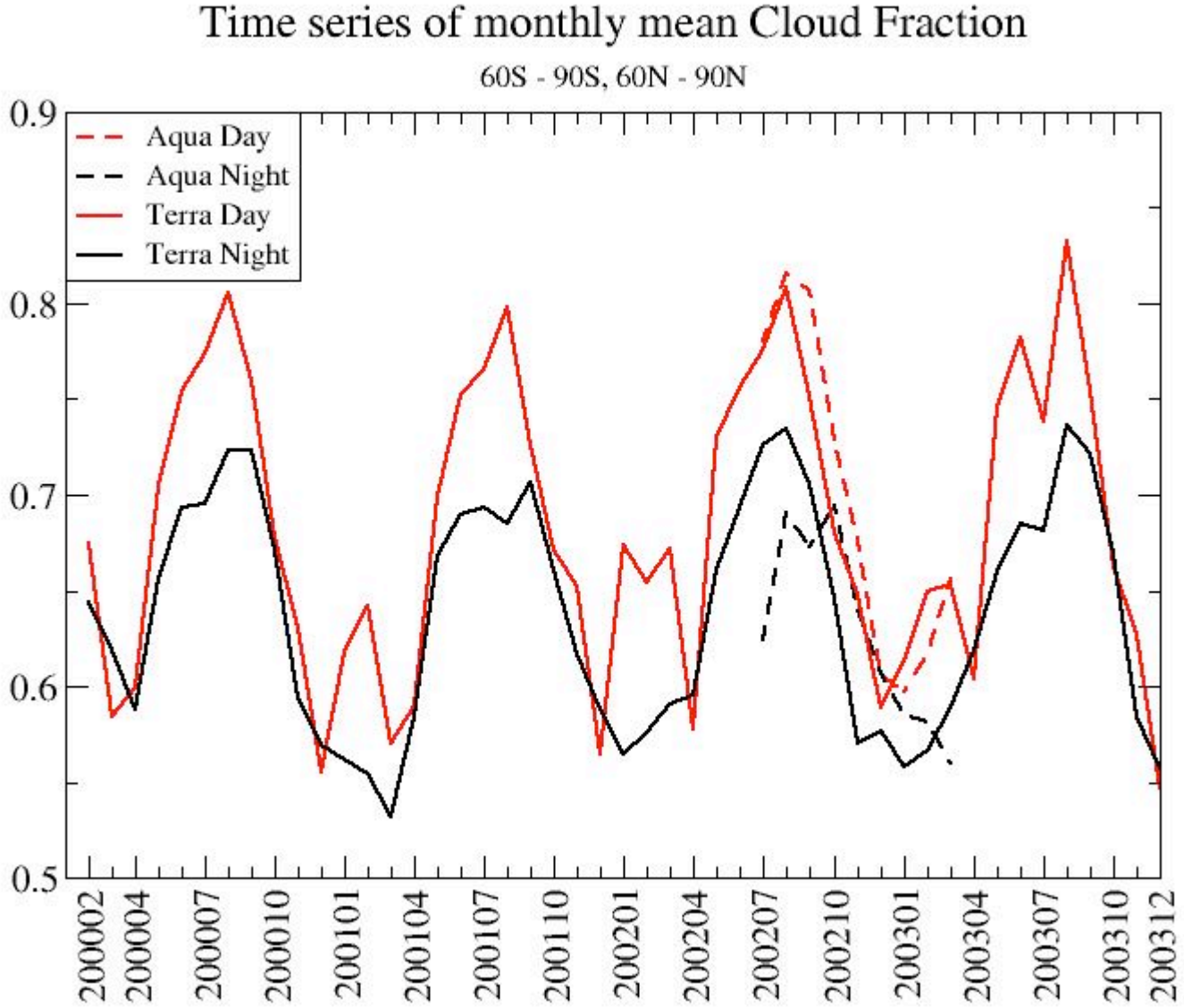
Aqua ice fraction ~4% greater during day, = Terra at night



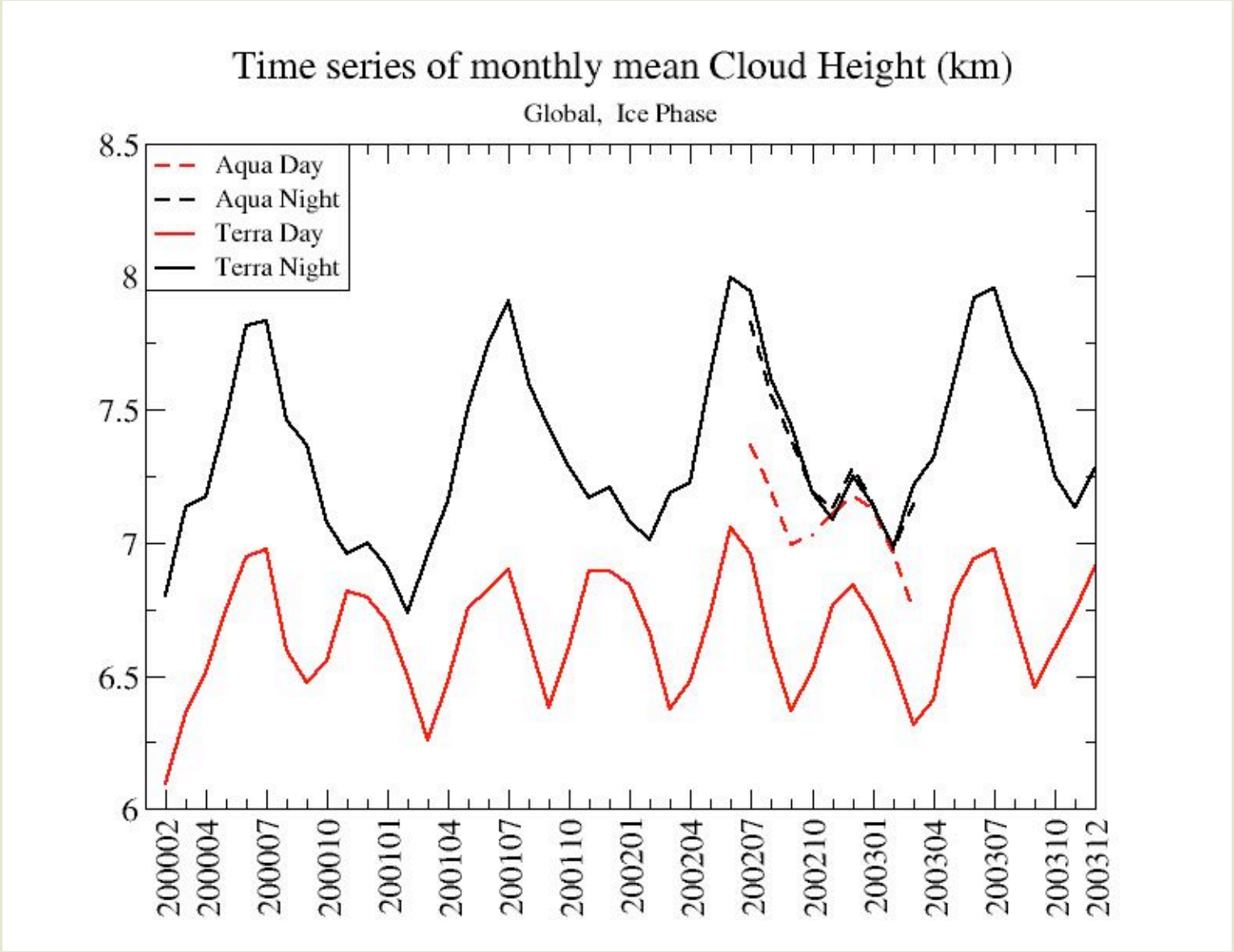
Aqua ~0-4% less during day, = Terra at night



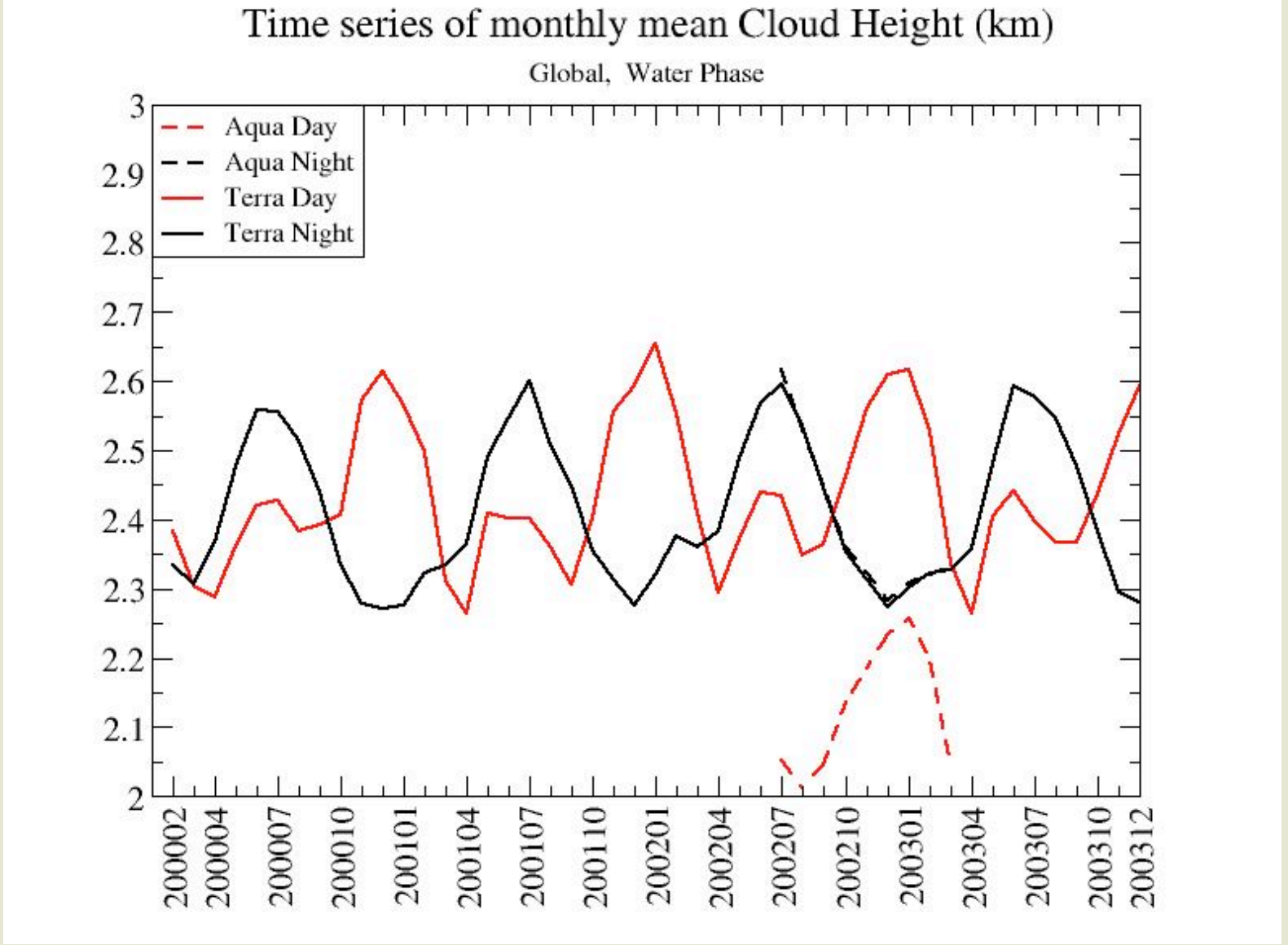
Aqua ~2-4% greater during day, = Terra at night



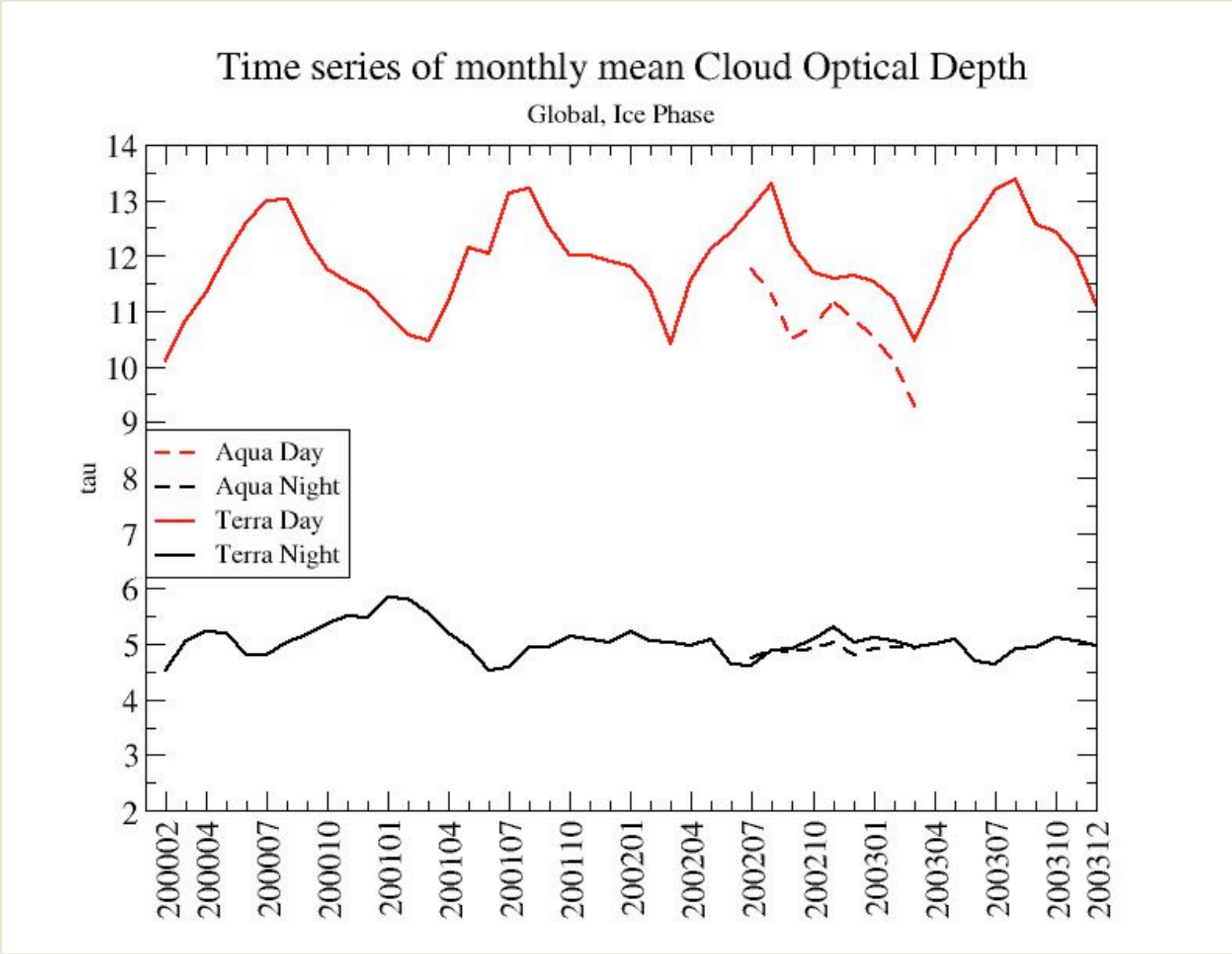
Aqua ~2% greater during day, 7% < to 4% > Terra at night



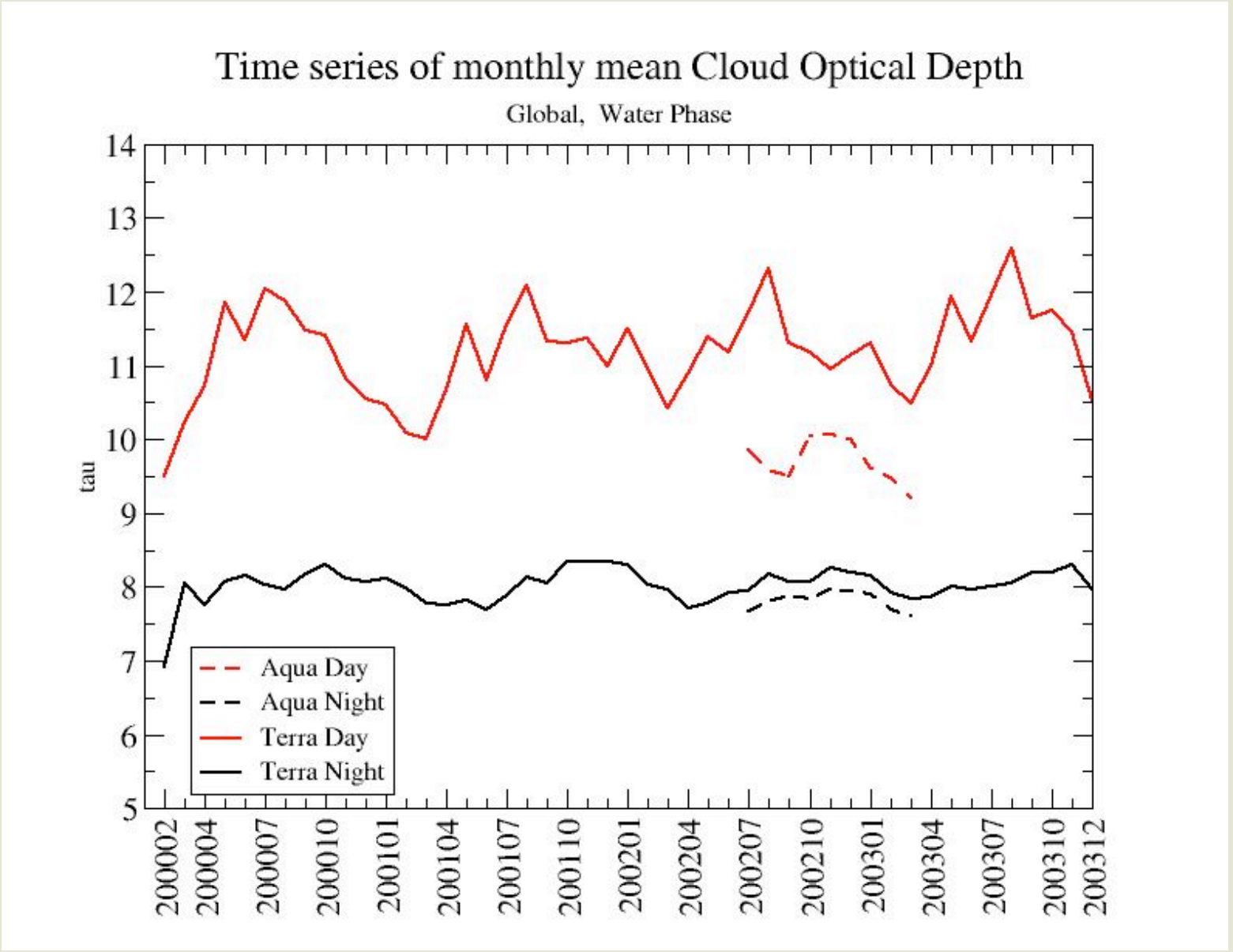
Aqua ~0.4 km higher during day, 0.2 km over nonpolar area and 0.6 km over polar regions



Aqua ~0.5 km lower during day, same over poles & nonpolar

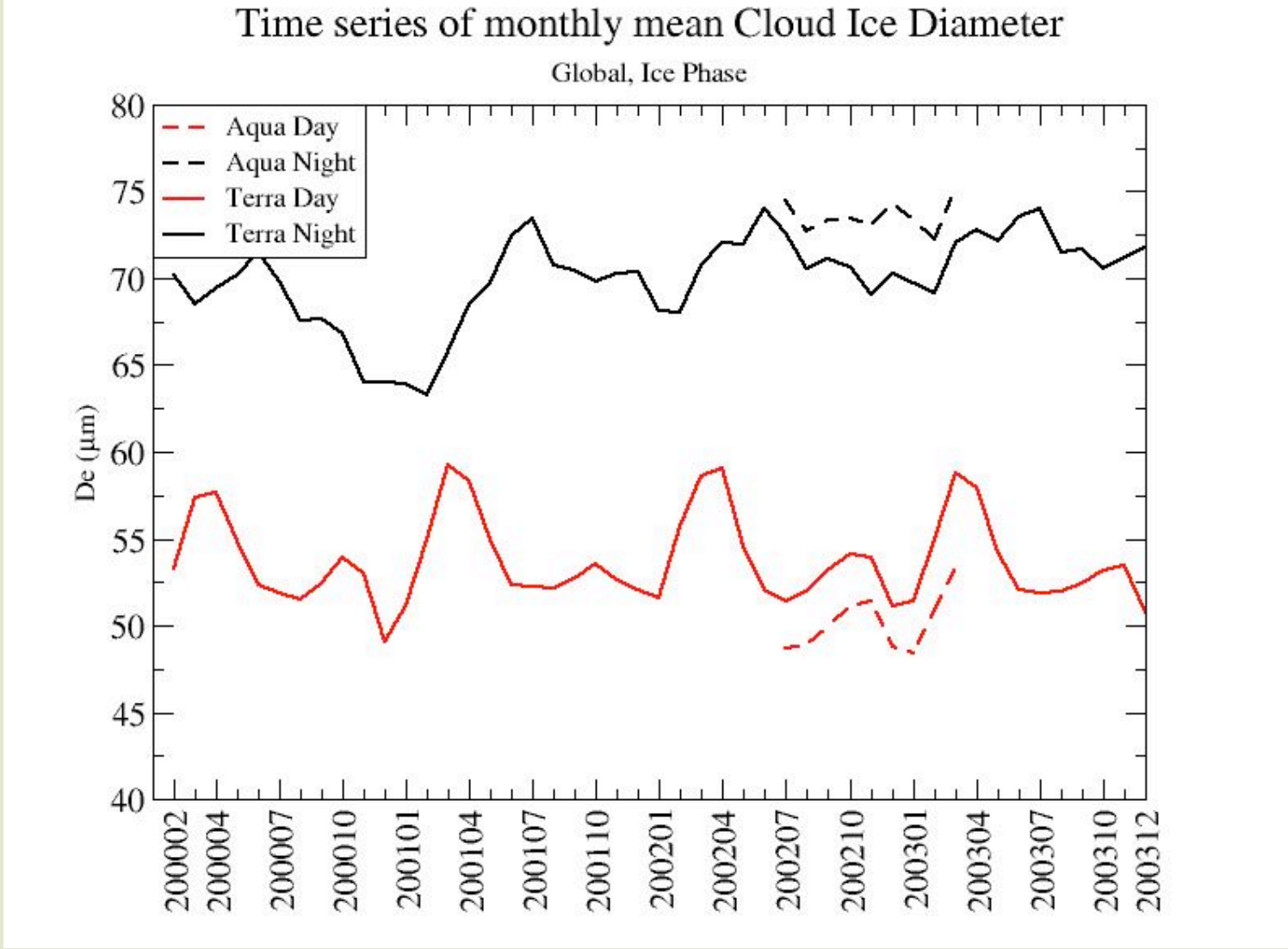


Aqua ~8% less during day, 6% in nonpolar areas

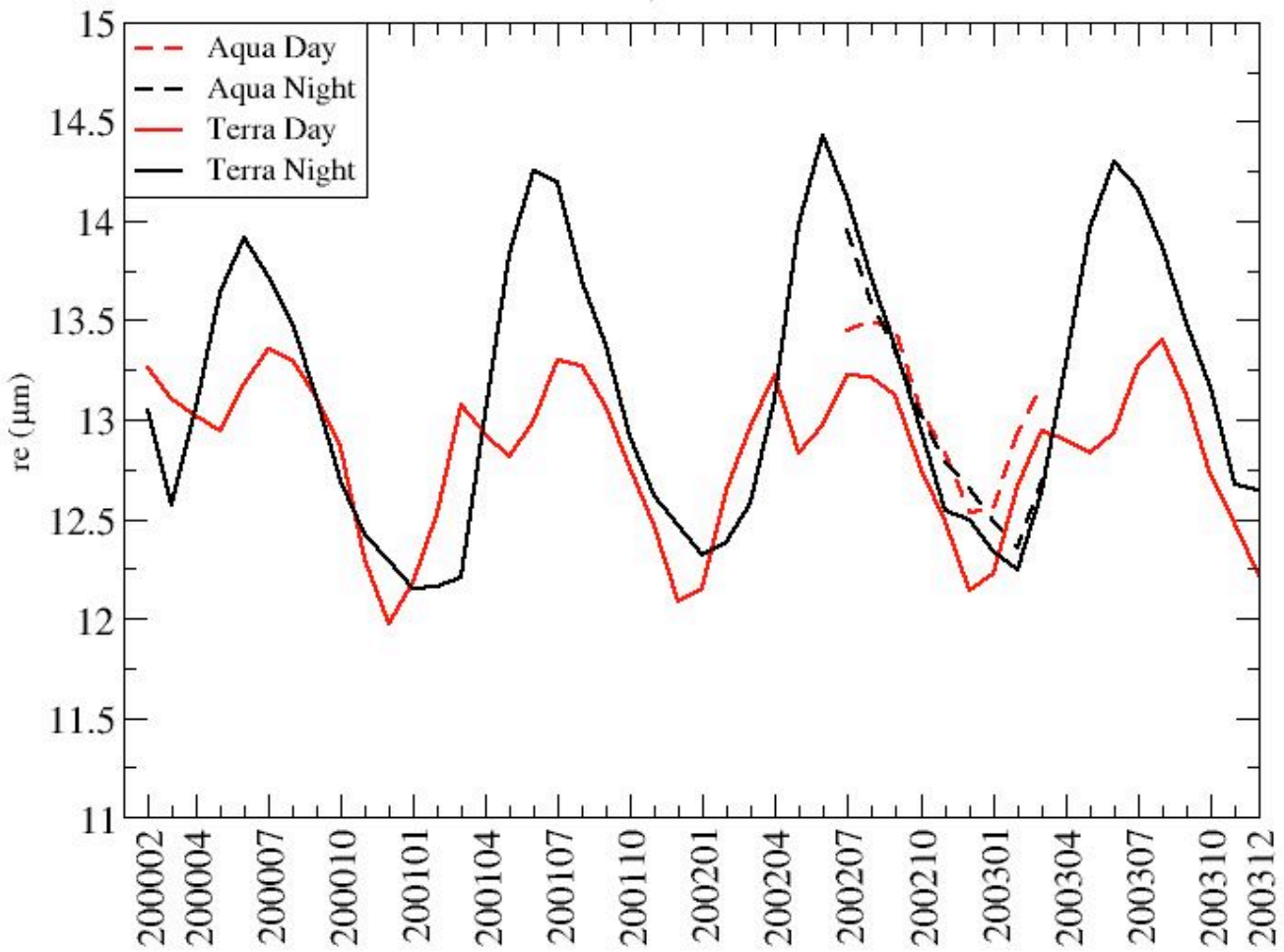


Aqua ~27% less during day, primarily due to polar regions

only 8% in nonpolar areas - *2.1 vs. 1.6 μm?*



Aqua ~4% less during day, 3% > Terra at night



Aqua ~3% greater during day, 3% > Terra at night

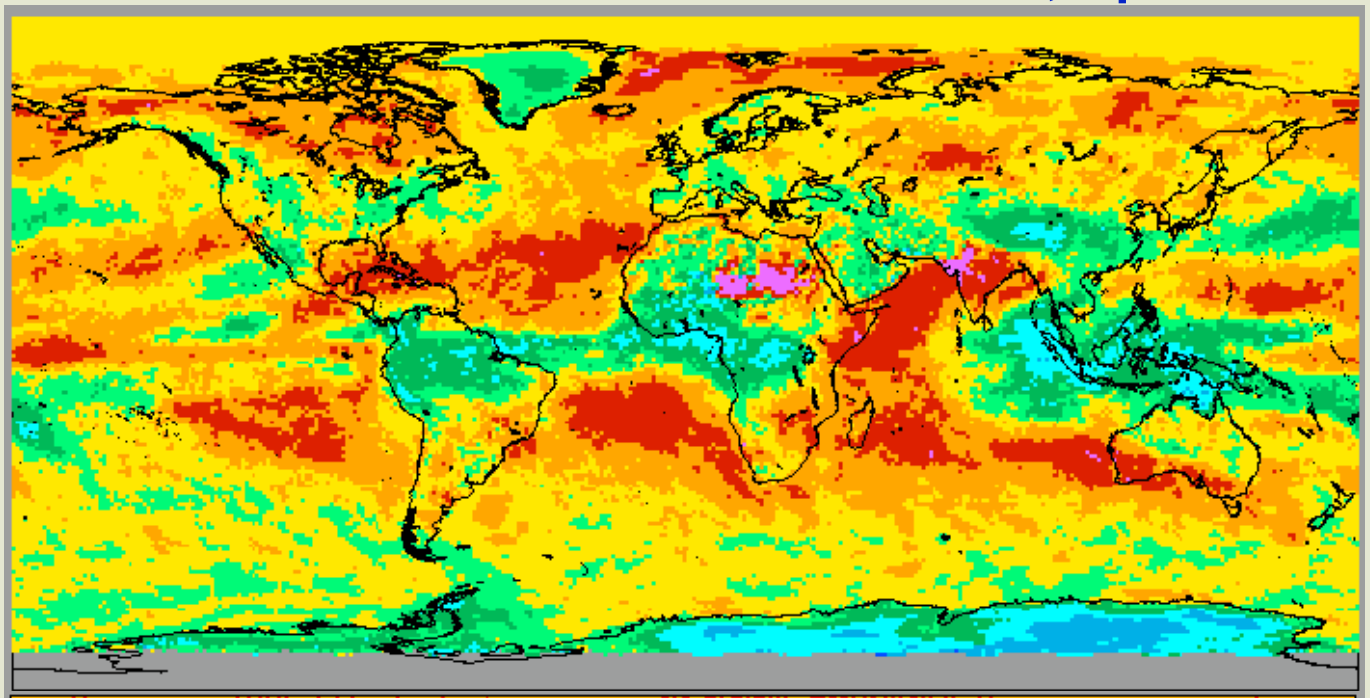
SUMMARY OF TERRA-AQUA CONSISTENCY

- Cloud fractions very consistent in pattern and magnitude
  - some differences over poles (2.13 vs 1.6 μm)
  - night most consistent
- More ice clouds from Aqua
  - probably thin cirrus and LBTM impact
  - lower ice OD, worse over poles
- Lower water cloud heights, higher ice cloud
  - some diurnal, some thin cirrus check
- Otherwise very consistent retrievals
  - thin cirrus check needs more investigation

DAYTIME TERRA CLOUD TOP PRESSURE, April 2000

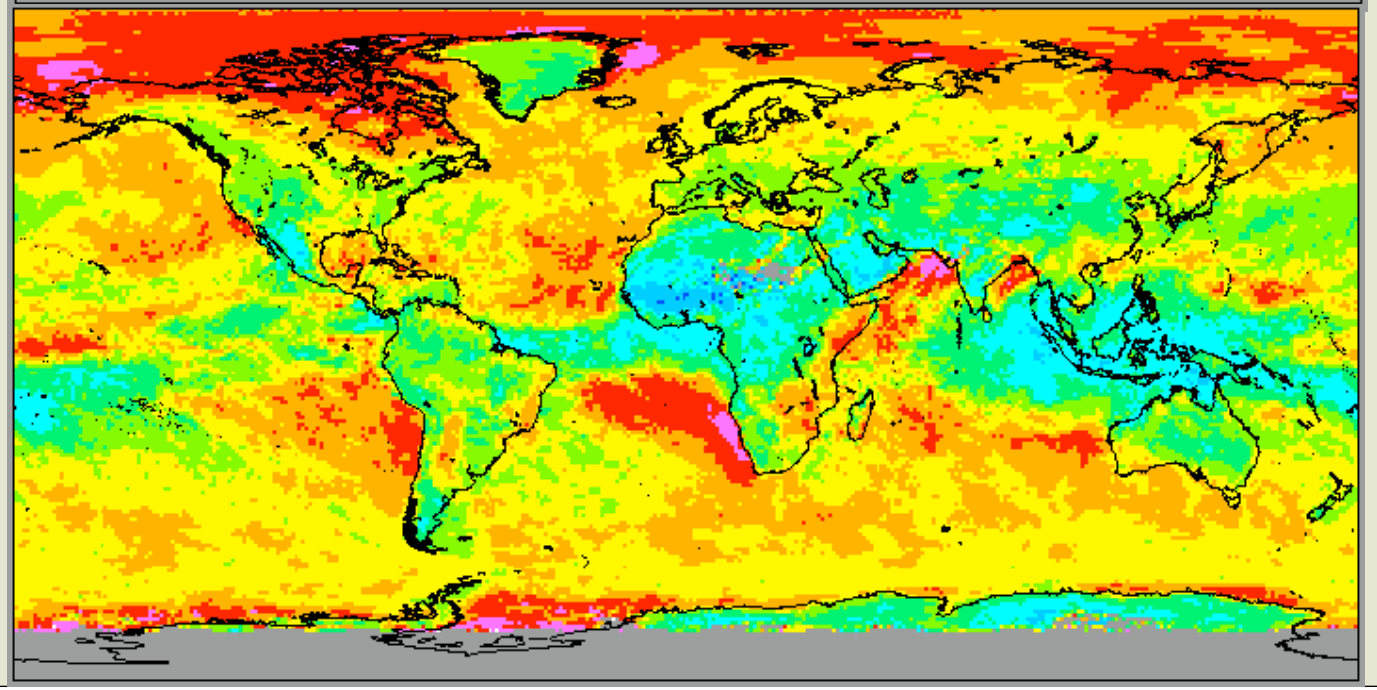
MOD08

MODIS TEAM

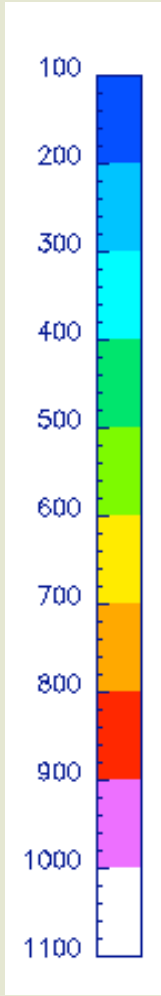


ED2

CERES



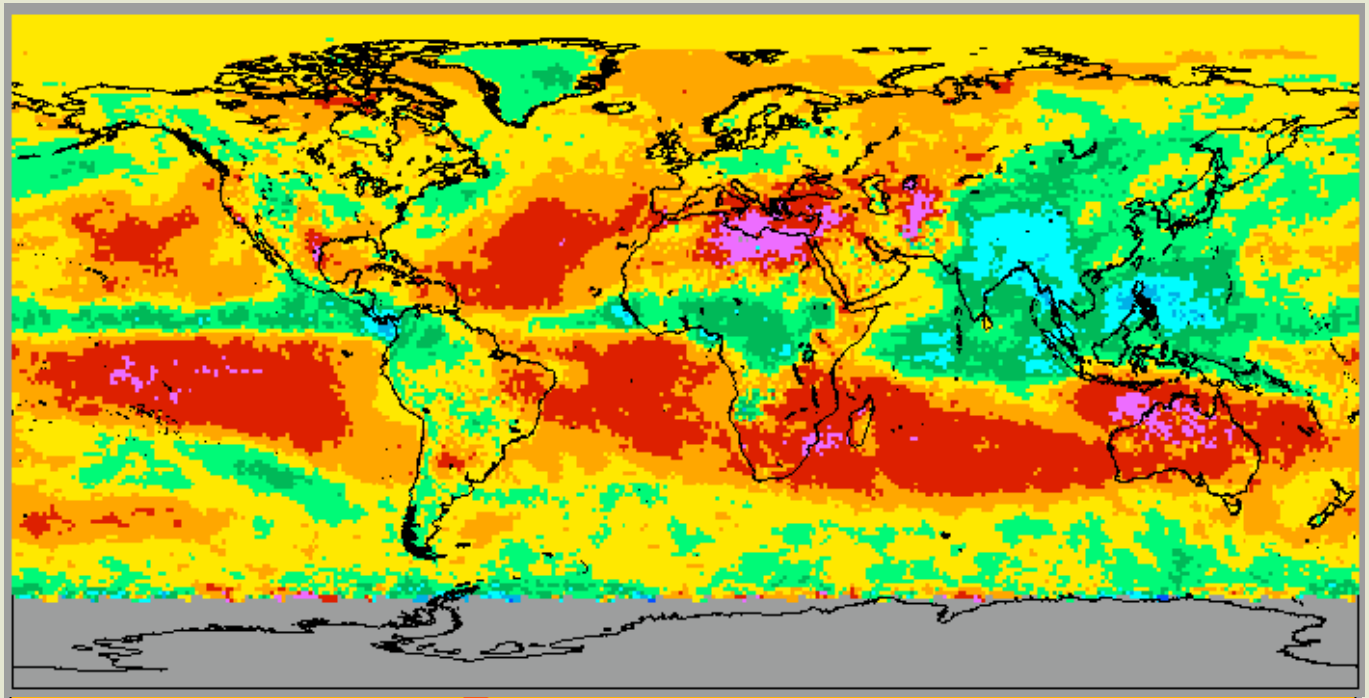
hPa



DAYTIME TERRA CLOUD TOP PRESSURE, JULY 2000

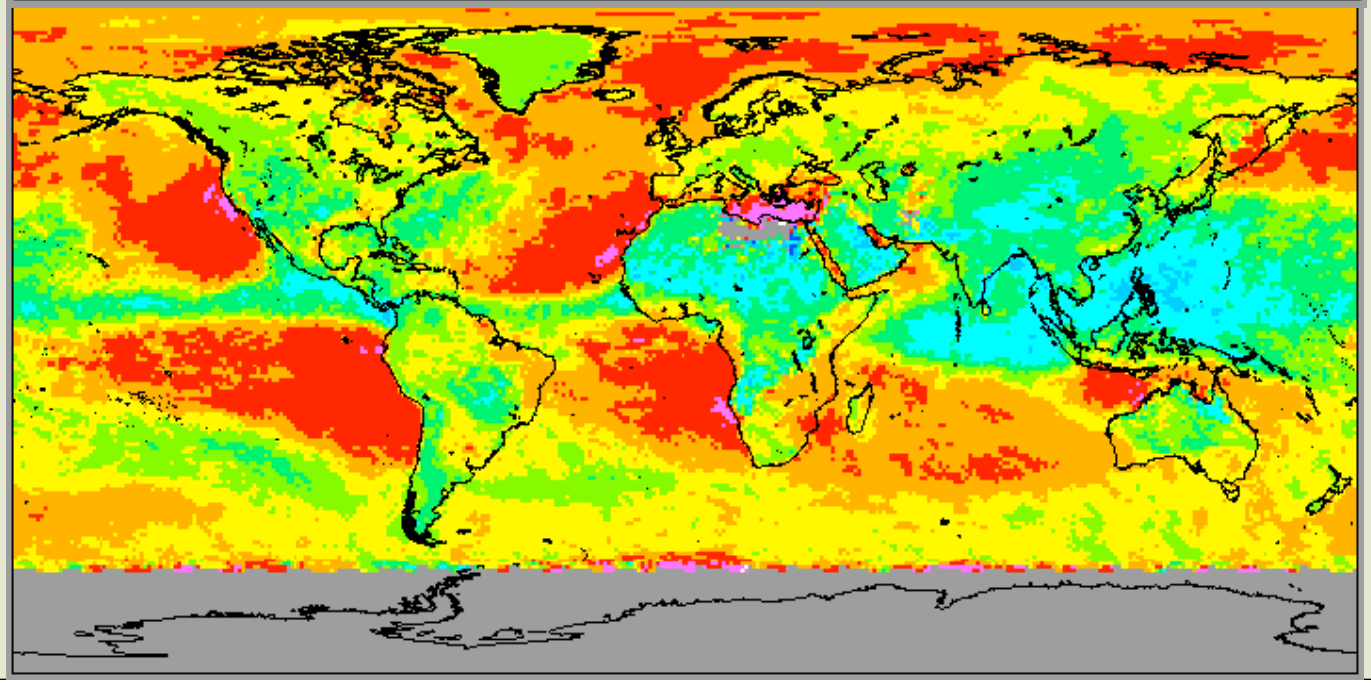
MOD08

MODIS TEAM

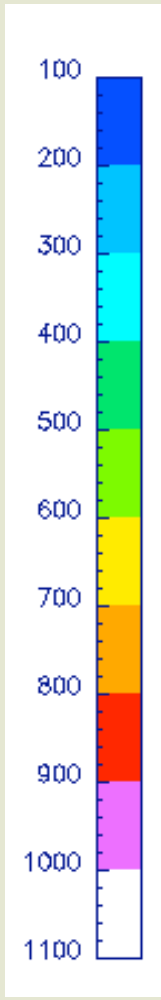


ED2

CERES



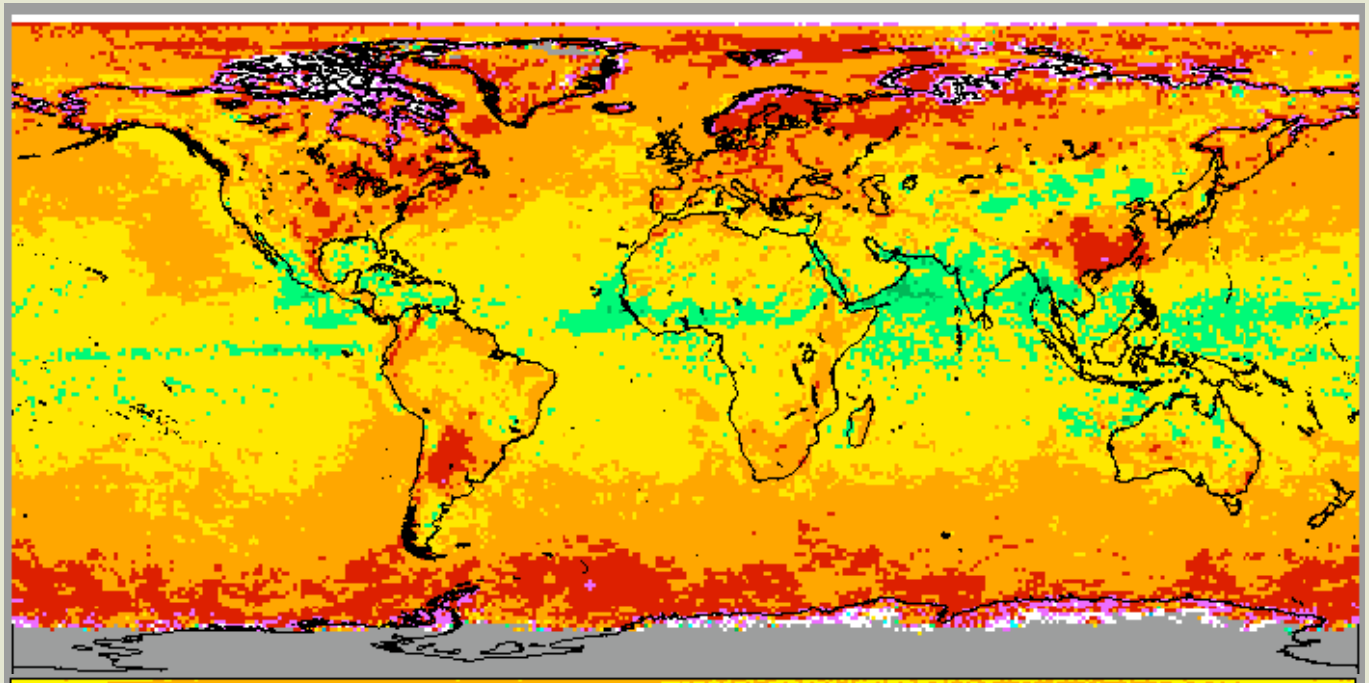
hPa



DAYTIME TERRA WATER CLOUD OPTICAL DEPTH, April 2001

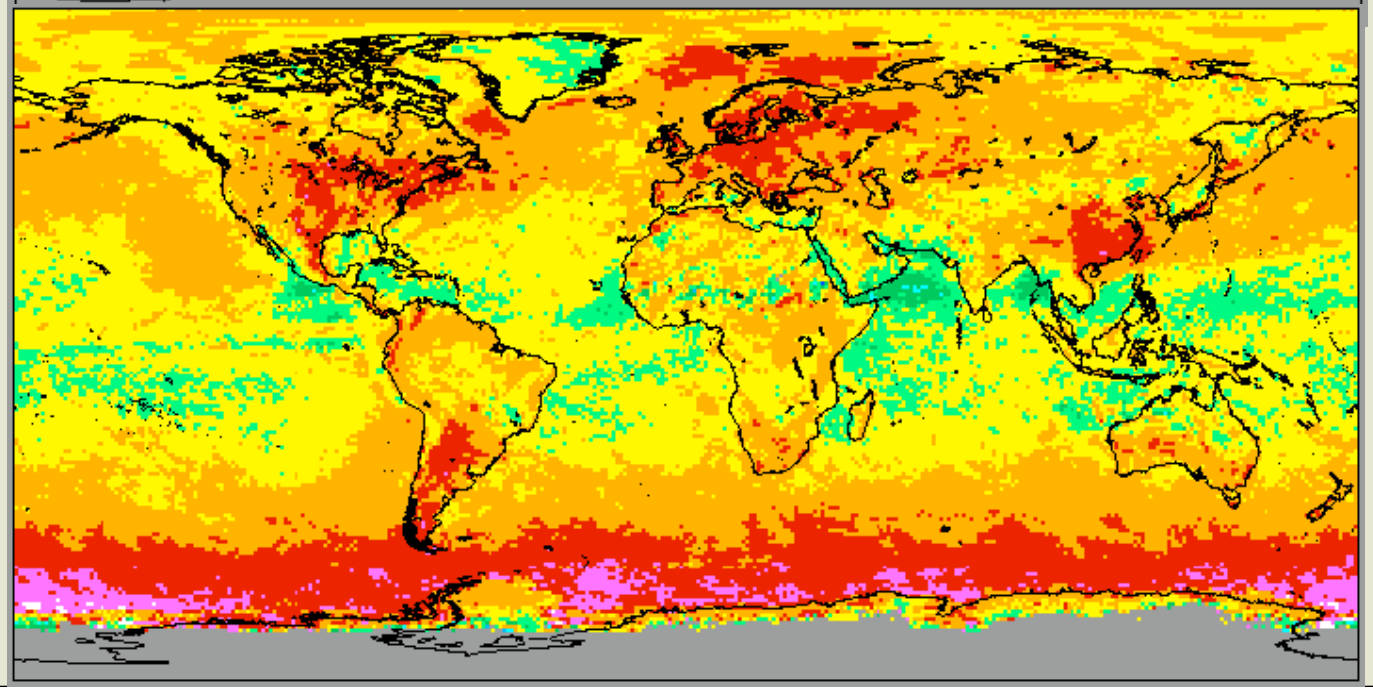
MOD08

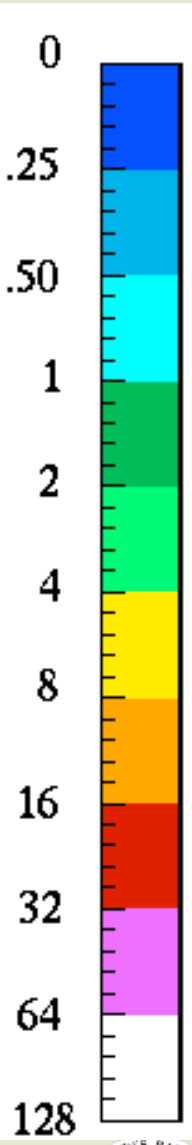
MODIS TEAM



ED2

CERES

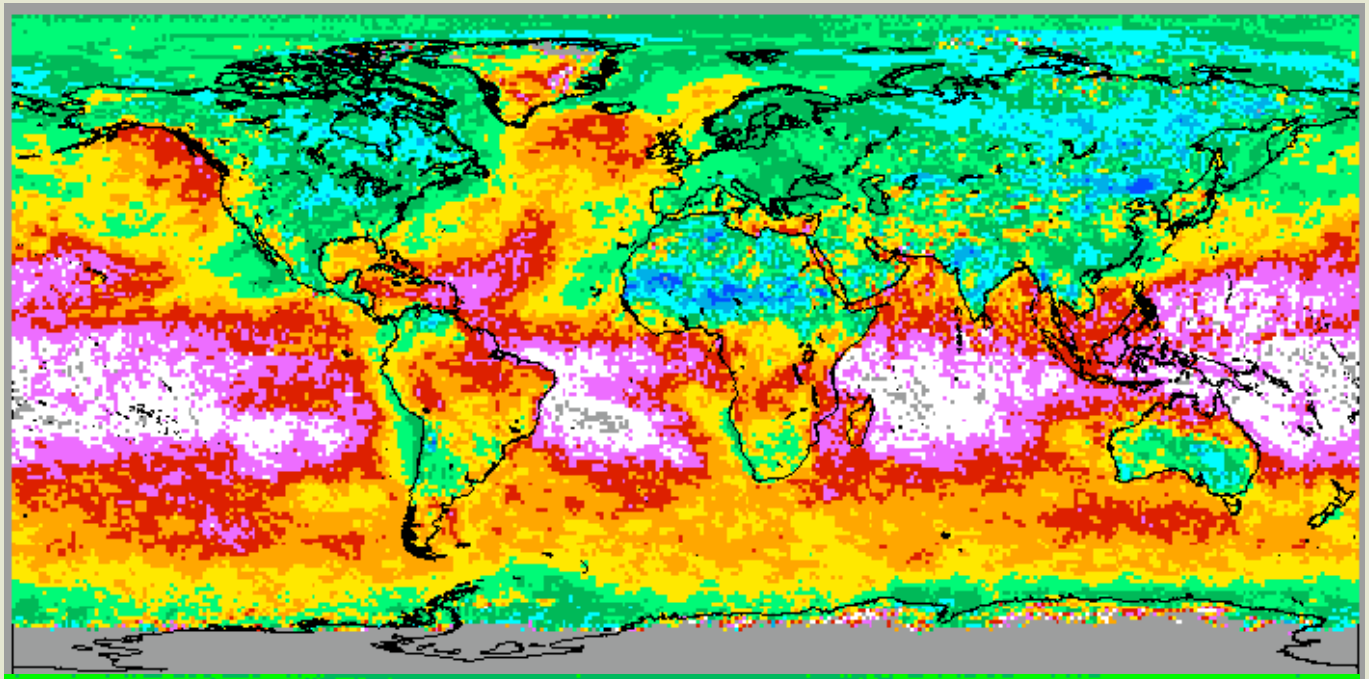




DAYTIME TERRA WATER DROPLET RADIUS, April 2001

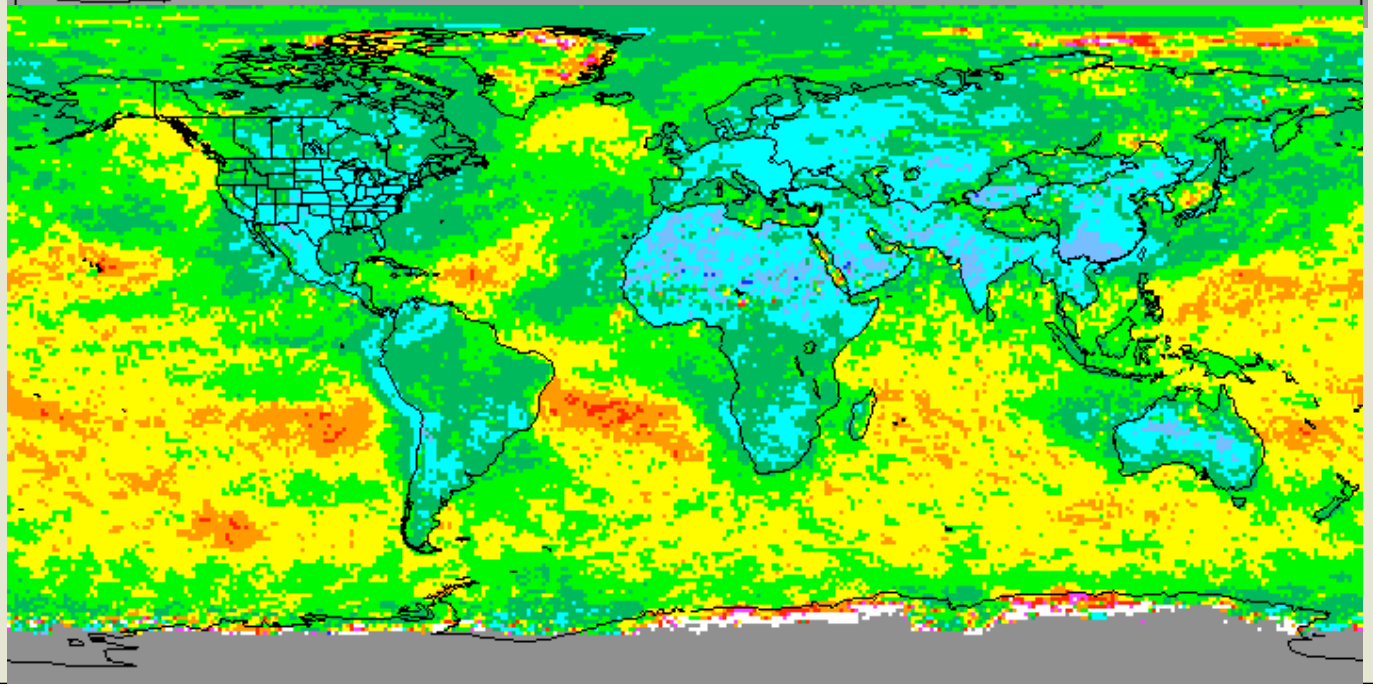
MOD08

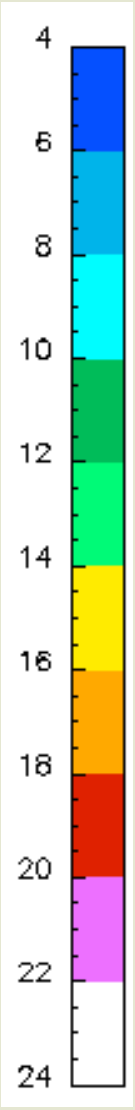
MODIS TEAM



ED2

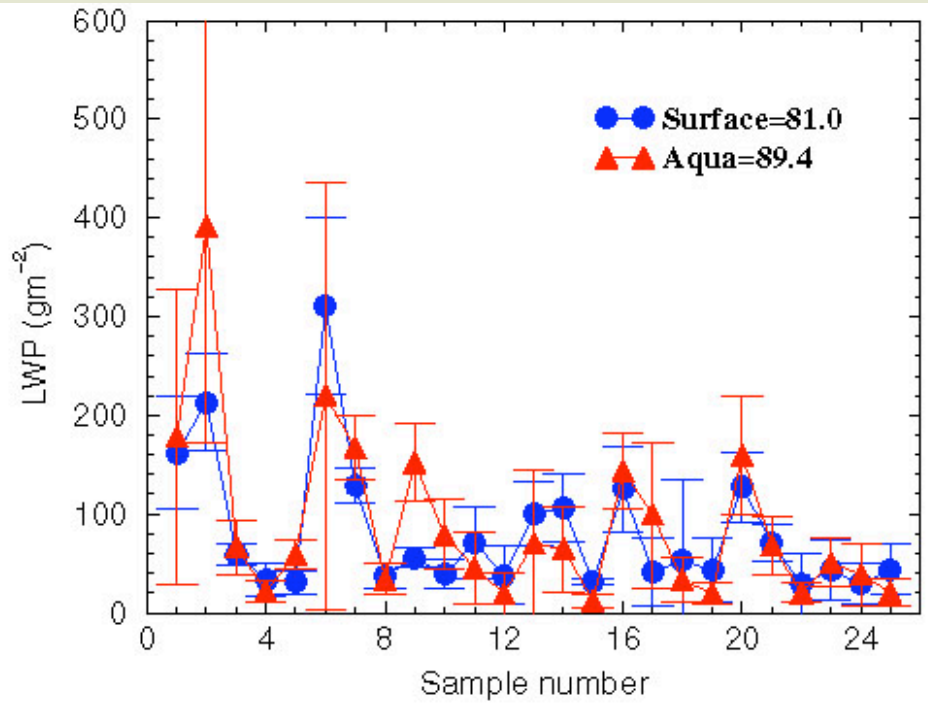
CERES

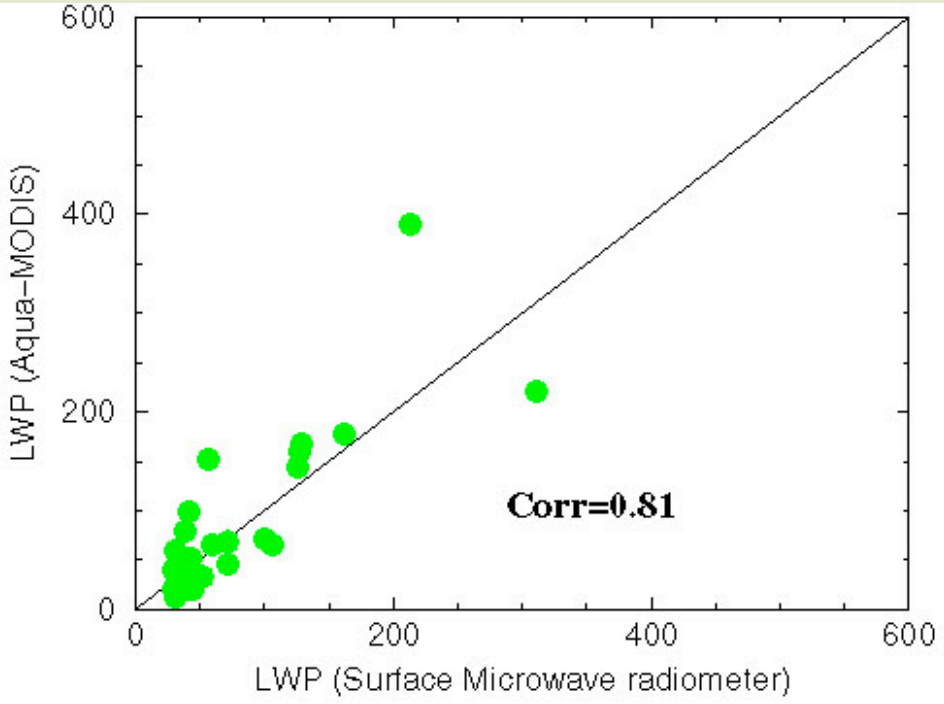




Aqua Validation

Initial look at LWP over ARM SGP site, July 2002-Feb 2003





- **LWP:** VIRS + 16% ($r^2 = 0.96$)

  Terra - 18% ($r^2 = 0.88$)

  Aqua + 10% ($r^2 = 0.81$)

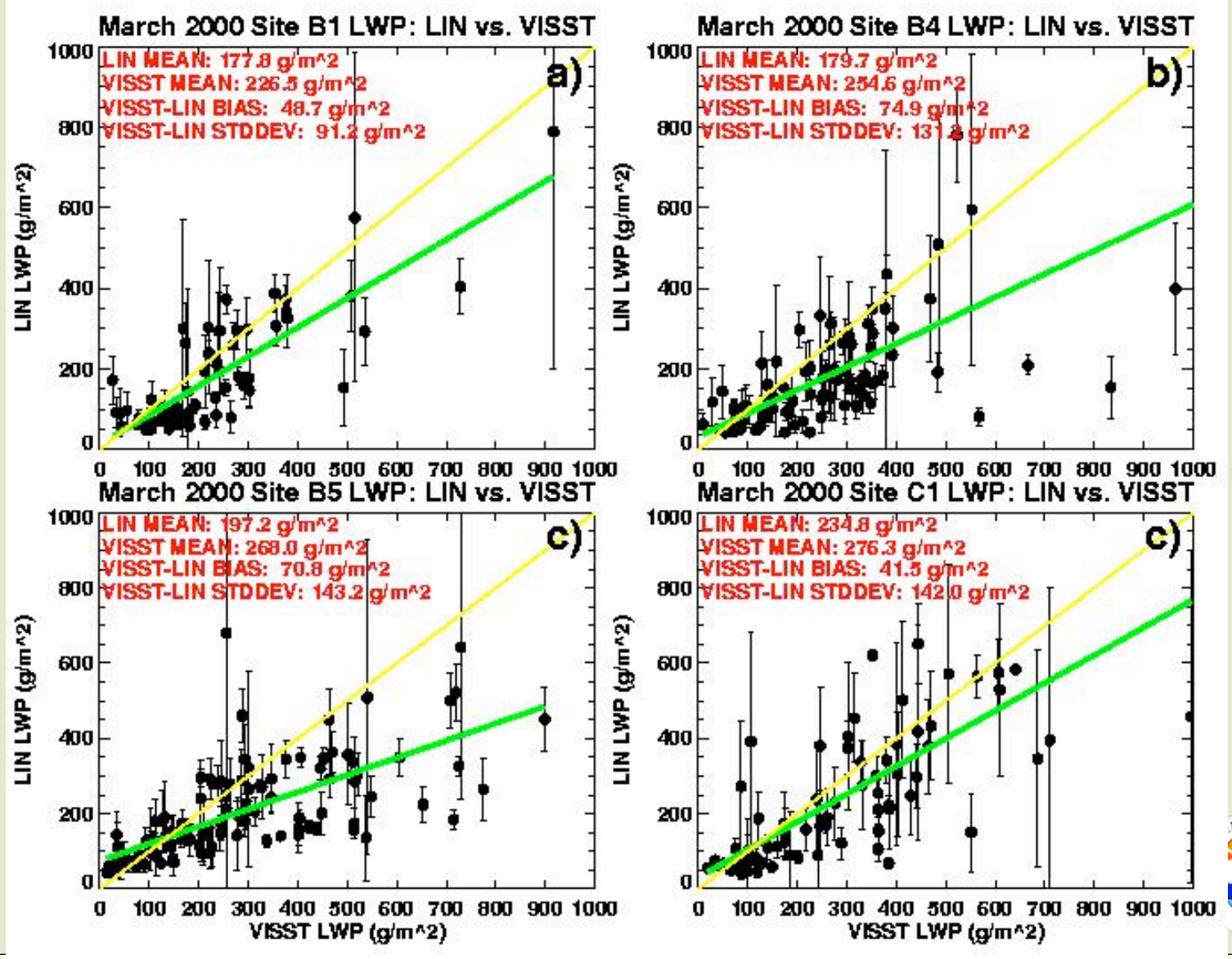
Standard errors ~ 50%

FUTURE IMPROVEMENTS

- LWP corrections
  - see a tendency of positive bias as cloud thickens due to vertical profile of re not seen with retrieval
- multilayered clouds
  - current method = early Baum 1.6/11 μm
  - new methods
    - BTD (Kawamoto et al., Heidinger et al.)
    - CO2 + imager (Fu et al.)
    - μ-wave + imager (Lin et al, Huang et al)

Comparison of GOES-derived LWP with SGP MWR retrievals

4 sites, 2000



Develop Correction for Vertical Variation of re using data from Main Site (C1)

$$LWPnew = LWP\ (1-F)$$

where

$$F = (0.000000157\ \tau_v^3 - 0.00004719\ \tau_v^2 + 0.00501574\ \tau_v - 0.028204)\ R_e / 12$$

MULTILAYERED CLOUD DETECTION & RETRIEVAL ALGORITHM DEVELOPMENT

BTD Optical depth Technique (BOT):

BTD = T11-T12 > 0 indicates optically thin cloud or water vapor

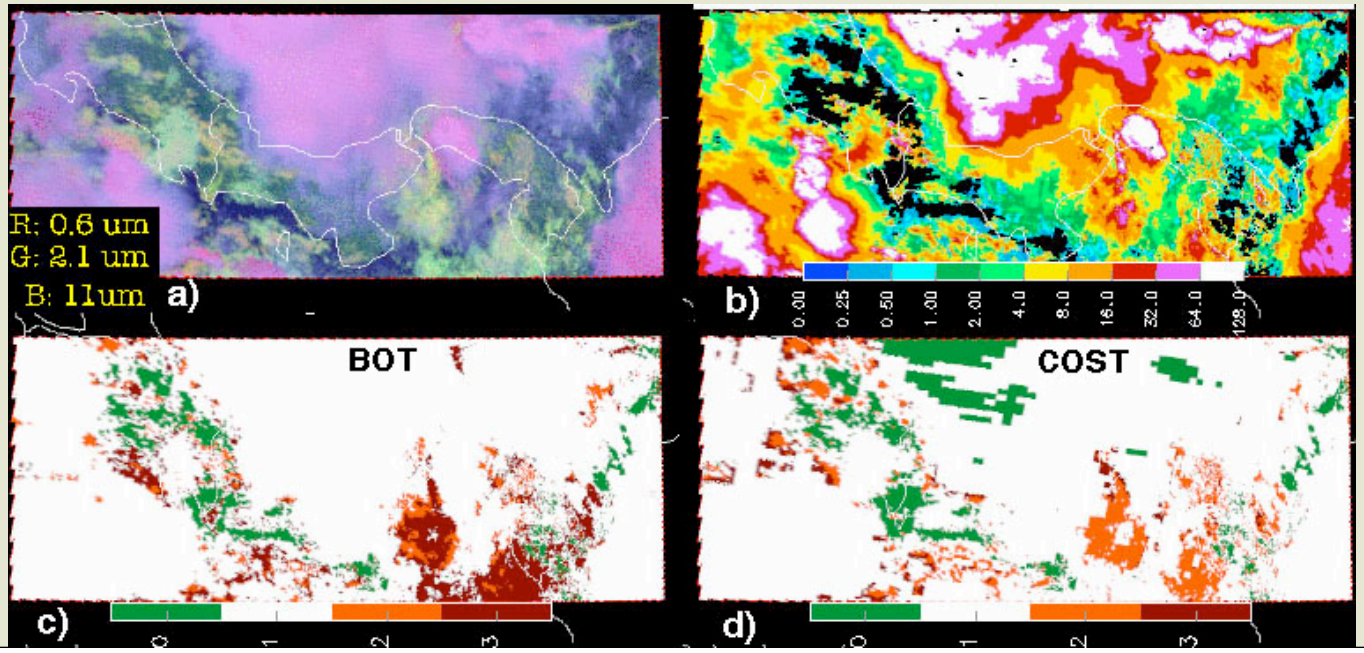
VISST retrieval yields phase, OD, and re/De

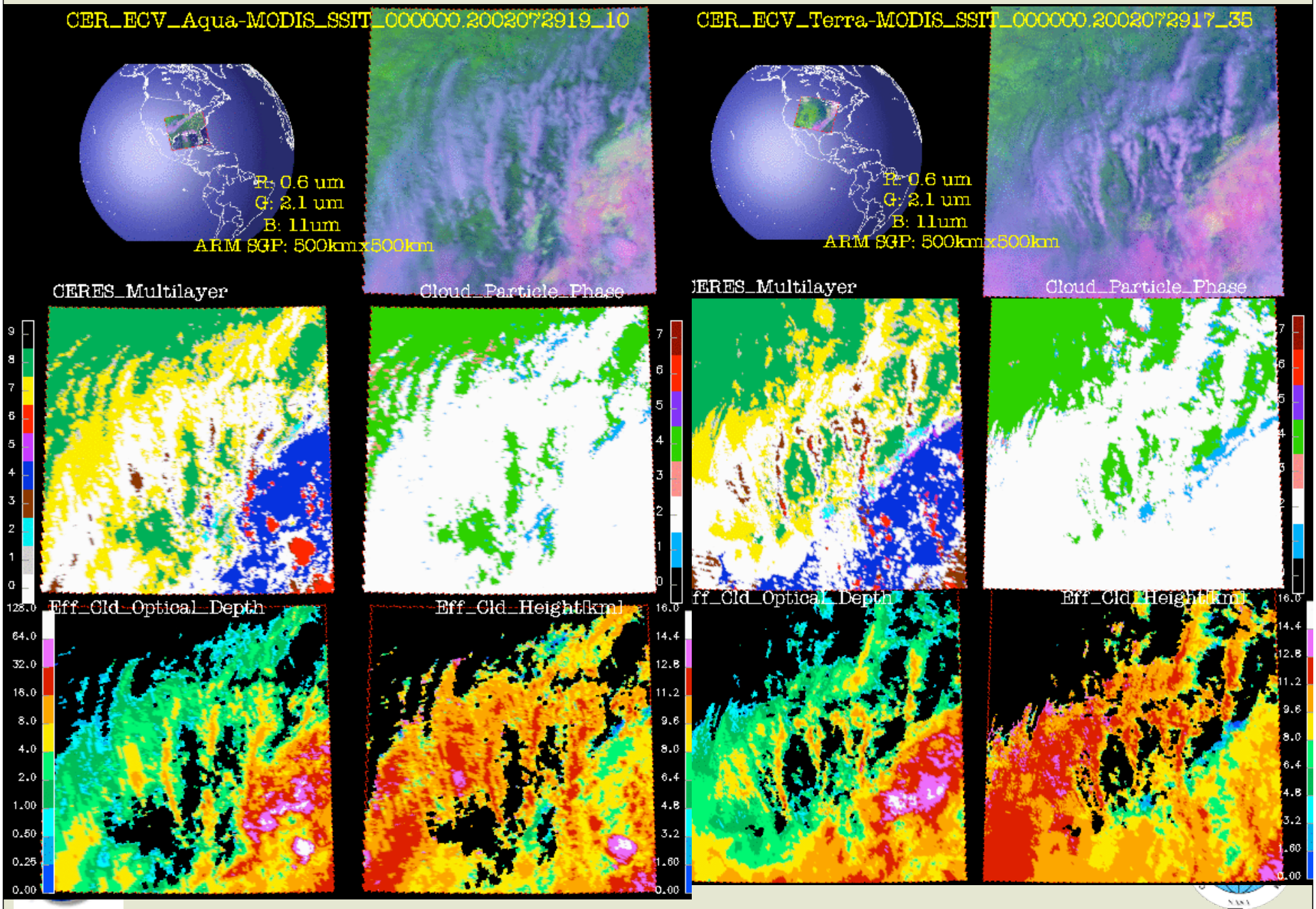
If OD large and cloud ice, but BTD > threshold, then overlap

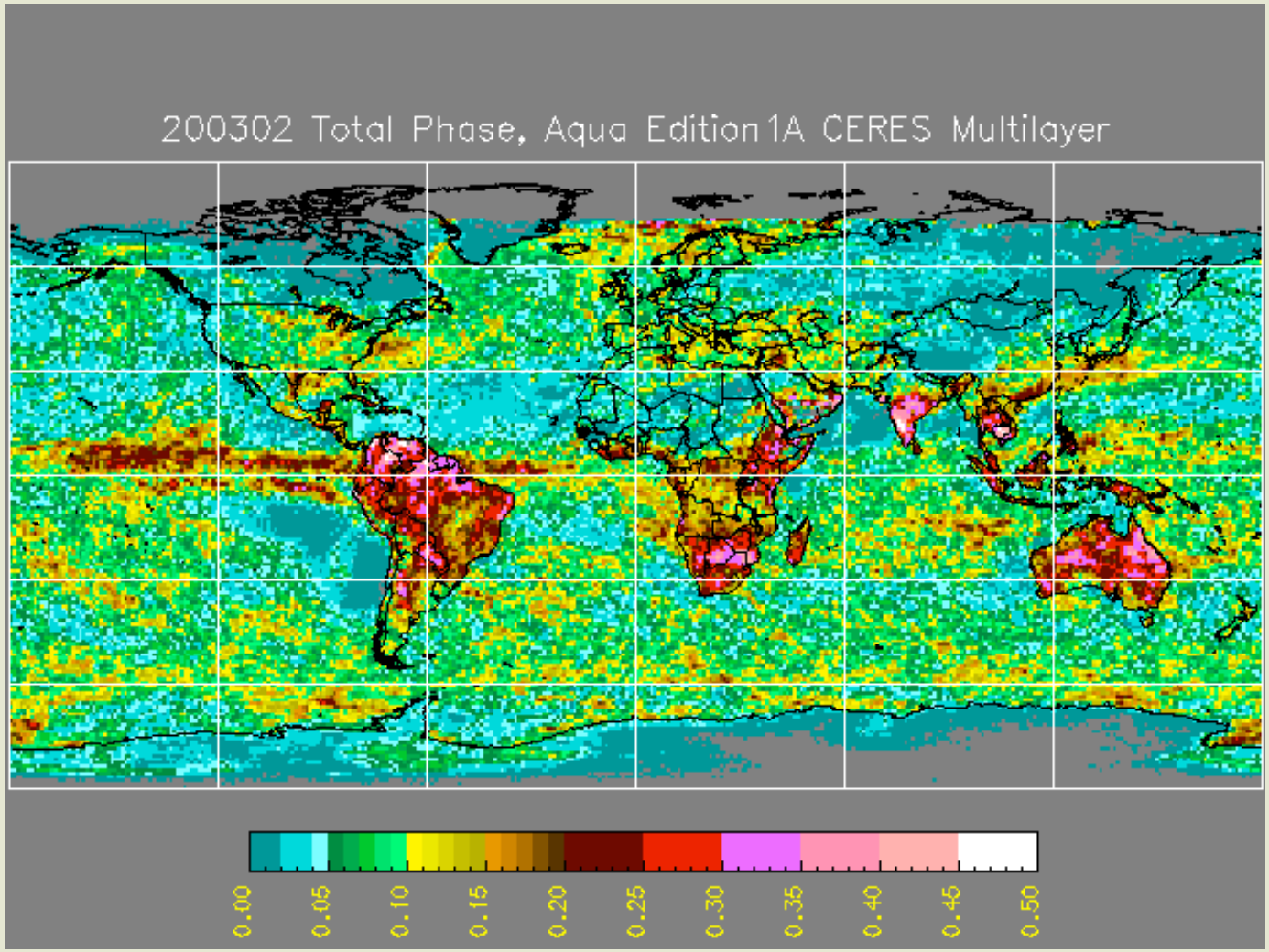
CO2 Slicing Technique (COST):

CO2-slicing indicates high cloud; VISST yields lower cloud

If OD large and cloud ice, but z(CO2)-z(VIS) > threshold, then overlap




CER_ECV_Aqua-MODIS_SSIT_000000.2002072919_10
R: 0.6 um
G: 2.1 um
B: 11um
ARM SGP: 500kmx500km
CERES_Multilayer
Cloud_Particle_Phase
Eff_Cld_Optical_Depth
Eff_Cld_Height[km]
CER_ECV_Terra-MODIS_SSIT_000000.2002072917_35
R: 0.6 um
G: 2.1 um
B: 11um
ARM SGP: 500kmx500km
CERES_Multilayer
Cloud_Particle_Phase
Eff_Cld_Optical_Depth
Eff_Cld_Height[km]


200302 Total Phase, Aqua Edition 1A CERES Multilayer
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50

FUTURE RESEARCH

- **multilayer cloud detection & interpretation**
  - combined microwave / VISST over ocean
  - secondary processing using info on BTD(11-12), τ, D_e/r_e

    => improved IWP assessment
- **improvement of nighttime/twilight everywhere including poles**
  - revise thresholds,include VIS in twilight, include 8.5 μm
  - improve surface emissivities
- **continued validation**
  - more continuous assessment at ARM sites
  - CALIPSO cloud height/amt global comparison
  - additional multiangle studies including MSG & GOES
  - in situ icing / microphysics field programs
- **subpixel cloud amounts**
  - combine hi-res VIS with lo-res multispectral (MODIS)

REFERENCES

List of references and pdfs given on the following web page.

http://www-pm.larc.nasa.gov/ceres/ceres-ref.html

Only imagery and summaries are available for CERES at the Cloud Working Web Page

http://lposun.larc.nasa.gov/~cwg/

Digital data avaialble at the LaRC DAAC

http://eosweb.larc.nasa.gov/HPDOCS/